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FOUNDED BY C. E. LINEBARGER

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The February issue will be of especial interest to teachers of biology. No teacher of biological science should miss it.

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SCHOOL SCIENCE AND MATHEMATICS

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EDITORIAL COMMENT AND NEWS.

The work of a high school teacher does not demand that he shall be an authority on subject matter. His training should be broad rather than deep. He should go far enough into one subject to understand how original investigators work and to learn to appreciate their problems, but if he attempts much research work himself he will not have time to give the necessary attention to subjects closely related to his major subject. A year or more of college work in several minors is essential: investigations show that a large percentage of teachers carry heavier programs in their minor subjects than in their majors. Moreover, the teacher who is fortunate enough to be able to confine his teaching to his major subject finds a knowledge of other subjects very valuable. It gives him perspective; it helps him gain the confidence and respect of his pupils; it shows him the relation of his subject to others. The biology or the psychology teacher who does not know the principles of physics is a cripple, and the physics teacher who does not know many of the applications of physics in biological processes misses a wonderful opportunity to teach the real value of his subject and thus lead many of his pupils to an abiding interest in the subject. Many of the failures in mathematics teaching are due to the fact that the teachers of this subject cannot point out the practical applications of mathematics.

Professional training in the principles, in the methods, and in the practice of teaching is essential. It starts the beginning teacher out right and eliminates many of the blunders commonly made by those who lack systematic training in education. We are not yet past the age in which young men and women enter the teaching profession merely as a stepping stone to some other

profession, but it is fast passing, and no one thing has been more effective in remedying this evil than the requirement in professional training.

After the preparation period is passed the high school teacher confronts the problem of keeping abreast of the times. This must largely be done by home study with an occasional summer school or evening school course. Much can be accomplished by the help of good professional journals. If a teacher can afford only one journal it should not be selected in a narrowly restricted field. It should be broad enough to show the progress that is being made in a group of subjects closely related to the teacher's major interest. A second journal restricted to the major subject should be added as soon as conditions permit. Certainly ten or fifteen dollars a year should not be considered an excessive outlay for professional literature; it is an investment.

We are pleased to announce the appointment of Mr. Homer W. LeSourd of Milton Academy, Milton, Massachusetts, as Departmental Editor of Physics. He takes the place left vacant a short time ago by Mr. Willis E. Tower, District Superintendent in Charge of Senior High Schools, Chicago, who resigned the editorship in order to devote his entire time to administrative work.

To many of our subscribers Mr. LeSourd needs no introduction. He received his elementary and high school education at Bellefontaine, Ohio, and graduated from Ohio Wesleyan University in 1898. After spending two years as science teacher in the Delaware, Ohio, High School he entered Harvard University graduate school and was granted the A. M. degree in 1901. His teaching experience includes a year as physics assistant at Harvard and a year as science teacher in the Pomfret School, Pomfret, Connecticut, before assuming his present position as head of the Science Department of Milton Academy. During 1928 he conducted a course in the Teaching of General Science in Harvard University School of Education and taught courses in the Teaching of Physics and General Science in Harvard University in the summer of 1929.

Mr. LeSourd is a member of the National Association for Research in Science Teaching and of the Eastern Association of Physics Teachers. In the latter association he has held the offices of secretary and of president one year each. Some of his other educational activities include a year each as Reader in

Physics and Examiner in Physics for the College Entrance Examination Board and a year as Chairman of the Science Committee of the Secondary Education Board. With this record it is needless to say that his broad practical teaching experience, a variety of educational interests and a good supply of energy admirably fit him for a place on our staff.

FROM THE SCRAPBOOK OF A TEACHER OF SCIENCE.

By Duane Roller,
The University of Oklahoma, Norman, Okla.

Shallow men believe in luck.—*R. W. Emerson in "Worship."*

As we speak of poetical beauty, so ought we speak of mathematical beauty and medical beauty.—*Blaise Pascal, French philosopher and mathematician, in "Thoughts."*

It is amusing to note that Boyle has been referred to as "the father of modern chemistry, and brother of the Earl of Cork."—*Ivor B. Hart, "Makers of Science."*

No one can estimate the value to the world of an investigator like Faraday or Pasteur or Millikan. The assets of our whole banking community today do not total the values which these men have added to the world's wealth.—*Herbert Hoover.*

There are things, ladies and gentlemen, better even than science. There are matters of the character as well as matters of the intellect, and it is always a pleasure to those who wish to think well of human nature, when high intellect and upright character are combined.—*John Tyndall, "Lectures on Light."*

One science only will one genius fit,
So vast is art, so narrow human wit:
. . . .
Like kings, we lose the conquests gain'd before,
By vain ambition still to make them more.
—*Alexander Pope, "Essay on Criticism."*

Art and science have their meeting point in method.—*Edward Bulwer-Lytton.*

Science itself, therefore, may be regarded as a minimal problem, consisting of the completest possible presentment of facts with the *least possible expenditure of thought.*—*Ernst Mach, "Science of Mechanics."*

When told that over 9000 experiments on the storage battery had been without results: "Results! Why man, I have gotten a lot of results! I have found 9000 things that won't work.—*Told of Thomas A. Edison.*

It is sometimes of great use in natural philosophy to doubt of things that are commonly taken for granted; especially as the means of resolving any doubt, when once it is entertained, are often within our reach.—*Sir William Herschel, German-English astronomer.*

VALENCE.

By Walter O. Walker,
William Jewell College, Liberty, Mo.

Proper concepts of valence are essential to the development of chemistry as evidenced by the endeavors of the early chemist to determine the combining ratios of the atoms. Without a valence concept, chemistry could not develop. In 1858 Kekule stated his two celebrated theories regarding the valence of carbon and its ability to form compounds. Kekule said that:

1. Carbon may unite with carbon.
2. The valence (combining power) of carbon is four.

Couper held similar views (failure to get an early publication partially robbed him of the honor due) but did not elaborate upon these theories as did Kekule. The effect of these theories upon the development of organic chemistry, especially, was most remarkable. They offered an intelligible interpretation of the structural relations existing in the organic molecule. It enabled the organic chemist to write the structural formula for a compound, as ethyl alcohol, in such a fashion as to indicate the adjacent atoms in the molecule.

```
    H
    |
H—C—H
    |
H—C—H
    |
    O—H
```

Kekule's theories cleared up the mystery of isomerism and showed why it was possible to have two substances, ethyl alcohol and di-methyl ether with the same empirical formulas by indicating the formula for the ether.

```
    H       H
    |       |
H—C—O—C—H
    |       |
    H       H
```

In addition, these theories enabled the chemist to associate definite characteristics with definite groups in the molecule leading to the formulation of the idea of multiple functions of large

molecules due to definite groups in them. The determination of the relation between the group and its characteristics has been of inestimable value in medicine where we find certain desirable properties associated with certain groups in a drug, as well as certain undesirable properties associated with other groups. Knowledge of the structure of the molecule enables the chemist to eliminate the undesirable properties through the elimination of the groups from which they emanate.

Following, and in many cases accompanying this development in organic chemistry, came a similar development in inorganic chemistry. A thorough study revealed the fact that all atoms and radicals had a characteristic combining power (with reference to hydrogen) represented by a small whole number less than eight. This combining power was called valence. Such a statement failed to carry with it an explanation of the source of this this peculiar affinity, in some cases, of certain atoms for one another and, in other cases, the lack of affinity. Efforts to explain the cause of this affinity began early in the history of chemistry. Van't Hoff (1, 2)[1] thought that this affinity was due to the force of gravity, but this was untenable since it was shown that the force of gravity was much less than the attractive forces between atoms. Moreover the force of gravity should allow all atoms to combine. Bayer (1, 2) proposed the idea that each atom might have hooks, probably a hook for each valence, by means of which connections might be made. In support of this suggestion, the action of bromine on the mucous membrane was cited as being caused by the scratching of the small hooks. Kekule (1, 2) did not suggest a positive explanation but stated that the forces were not electrical. Today we know that the forces holding atoms are electrical or magnetic or both. Perhaps the first explanation, employing an electrical conception, was made by Davy (1, 2). The following illustrates the important points in his theory. An element, such as zinc, unites with an element such as sulfur, because the zinc has acquired a positive charge and the sulfur a negative charge, the atoms being held together by the electrostatic attraction. Davy based his theory upon the facts (partial in this case) of electrolysis. He first prepared metallic sodium, by the electrolysis of fused sodium hydroxide. He looked upon the liberation of sodium as being due to the neutralization of the positive charge of the sodium ion; a thoroughly modern interpretation. However, he overstepped

[1]Numbers refer to bibliography.

his theory in believing that any two elements in contact would unite. Obviously this is not supported by experimental facts. Berzelius (1, 2) (the Dualistic Theory) stated that the electricity appearing on the atom is inherent to it. Atoms are held together by these charges. His mistake consisted in assuming that the more active an element, the greater its electrical charge (Faraday disproved this in his law of electrolysis) and that an element is always either negative or positive.

The inability of the last two theories to deal adequately with the entire problem of an electrical explanation of valence resulted in the stating of several non-electrical theories, mostly planetary in nature. In 1881, Helmholtz (1, 2), delivering the Faraday lecture in London, proposed a theory based on Faraday's law of electrolysis. He pointed out that 96,500 coulombs (one Faraday) of electricity deposits, from solution, one equivalent of an element. To illustrate:

$$\begin{array}{ll} 1 & \text{g. of H from HCl} \\ 35.5 & \text{g. of Cl from HCl} \\ \frac{63}{2} & \text{g. of Cu from } CuCl_2 \\ \frac{56}{2} & \text{g. of Fe from } FeCl_2 \\ \frac{56}{3} & \text{g. of Fe from } FeCl_3 \end{array}$$

Helmholtz reasoned that the explanation for the above experimental work lay in the assumption of the atomic nature of electricity. He further stated that the electrical formulas for the examples mentioned are:

$$\overset{+}{H}\overset{-}{Cl}$$
$$\overset{++}{Cu}\overset{=}{Cl_2}$$
$$\overset{++}{Fe}\overset{=}{Cl_2}$$
$$\overset{+++}{Fe}\overset{\equiv}{Cl_3}$$

The atoms are held together by their equal and opposite charges, each atom having a characteristic charge. Moreover atoms might be positive or negative, depending on the circumstances.

J. J. Thompson (14) supplemented this idea by the suggestion that the development of a charge on an atom is due to the loss or gain of a small unit of electricity, the *electron*.

Contemporaneous with these developments, came many other theories of valence, a brief account of several being given in the following discussion. Thiel's (4) Partial Valence refers to the theory of the double bond. Werner (4) looked upon the atom as being spherical, homogeneous, and of a definite size. The property of attraction emanated from the center and not from the surface of the atom. His theory is especially valuable (in its final form) in dealing with the inorganic complex compounds of the Co, Pt, Cr, type. Kauffmann (4) stated that the atoms are held together by a series of lines (valence field), while Hinsberg (4) thought that valence centers were located in the atom. Stark (4) assumed, from the study of spectral lines and other experimental data, that:

(1). Chemical elements disintegrate to form electrons. These electrons are the same for all atoms.

(2). The loss of an electron leaves the element with a positive charge, while the gain of an electron leaves the element with a negative charge.

This called for the division of all atoms into electro-positives, electro-negatives and electro-duals. The latter case is illustrated by means of the union between hydrogen and carbon. See Fig. 1. This is perhaps the first suggestion of the *pairing of electrons,*

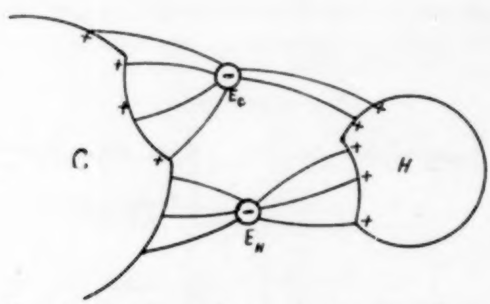


FIG. 1—THE STARK CONCEPTION OF THE CARBON-HYDROGEN BOND.

which later is so admirably applied by Lewis. In spite of its many fine qualities, Stark's theory failed to impress chemists in general.

The remainder of this paper will deal with the discussion of valence theories conforming to the four major theories of atomic structure (10).

The Kossell Theory.

J. J. Thompson (14) enunciated the principle of the loss or gain of electrons as the basis of the development of an electrical charge on the atom. To illustrate:

$$\overset{+}{\mathrm{Na}}\overset{e}{\rightarrow}\overset{-}{\mathrm{Cl}}$$

The electron is assumed to have passed completely from the sodium atom to the chlorine atom as indicated by the arrow. This results in the development of a positive charge on the sodium atom and a negative charge on the chlorine atom. Since this subject has been dealt with in previous papers of the writer (8, 9) no further illustrations will be offered. However, proof of the validity of the above interpretation must be given if we are to have any faith in this theory of valence. These proofs will be grouped under three heads.

(1). Electrolysis.

Electrolysis of sodium chloride results in the liberation of sodium at the cathode (mercury cathode) and chlorine at the anode. This could not occur without each ion possessing a definite and distinctive charge. See also the relations specified in the Faraday law of electrolysis.

(2). The production of an electric current by chemical reactions.

The voltaic cell is a good example of this phenomenon. (See Fig. 2.) Zinc goes into solution as zinc ion (Zn++) leaving the

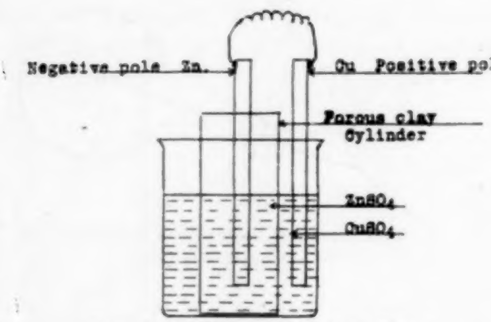


Fig. 2—A Simple Voltaic Cell.

electron equivalent on the zinc electrode, thus producing the negative terminal. Copper is deposited from solution at the copper electrode, by absorbing electrons from the metallic copper, thus producing the positive electrode.

The electrode reactions.

$$Zn \rightarrow Zn^{++} + 2e$$
$$Cu^{++} + 2e \rightarrow Cu$$

For fuller discussion see Stieglitz (11).

3. Ionization.

$$NaCl \rightleftarrows Na^{+} + \overline{Cl}$$

The meaning of the above equilibrium is too well established to call for further discussion here. Following ionization and being derived from it are the principles for the guidance of the direction of reactions. To illustrate:

$$CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O.$$

We never get another pair of products (with the above proportions) such as we might expect if there were no guiding electrical charges on the ions involved.

In the following:

$$PCl_3 + 3H_2O \rightarrow P(OH)_3 + 3HCl.$$
$$NCl_3 + 3H_2O \rightarrow NH_3 + 3HOCl.$$

we should expect to get the same type of product in each case or at any rate a mixture, since phosphorus and nitrogen are quite closely related by chemical properties. However we get the indicated products. Examination of these reactions shows that we may interpret their choice of direction by the electrical charges on the ions as indicated in these ionic equations.

$$\begin{array}{lllllll}
 & \overset{-}{\mathrm{Cl}} & \overset{+}{\mathrm{H}}\ \overset{-}{\mathrm{OH}} & & \overset{-}{\mathrm{OH}} & \overset{+}{\mathrm{H}}\ \overset{-}{\mathrm{Cl}} \\
\mathrm{P}^{+++} & \overset{-}{\mathrm{Cl}} + & \overset{+}{\mathrm{H}}\ \overset{-}{\mathrm{OH}} & \rightarrow \mathrm{P}^{+++} & \overset{-}{\mathrm{OH}} + & \overset{+}{\mathrm{H}}\ \overset{-}{\mathrm{Cl}} \\
 & \overset{-}{\mathrm{Cl}} & \overset{+}{\mathrm{H}}\ \overset{-}{\mathrm{OH}} & & \overset{-}{\mathrm{OH}} & \overset{+}{\mathrm{H}}\ \overset{-}{\mathrm{Cl}}
\end{array}$$

$$\begin{array}{lllllll}
 & \overset{+}{\mathrm{Cl}} & \overset{+}{\mathrm{H}}\ \overset{-}{\mathrm{OH}} & & \overset{+}{\mathrm{H}} & \overset{-}{\mathrm{HO}}\ \overset{+}{\mathrm{Cl}} \\
\mathrm{N}^{---} & \overset{+}{\mathrm{Cl}} + & \overset{+}{\mathrm{H}}\ \overset{-}{\mathrm{OH}} & \rightarrow \mathrm{N}^{---} & \overset{+}{\mathrm{H}} + & \overset{-}{\mathrm{HO}}\ \overset{+}{\mathrm{Cl}} \\
 & \overset{+}{\mathrm{Cl}} & \overset{+}{\mathrm{H}}\ \overset{-}{\mathrm{OH}} & & \overset{+}{\mathrm{H}} & \overset{-}{\mathrm{HO}}\ \overset{+}{\mathrm{Cl}}
\end{array}$$

Unless there is a guiding action exerted by the electrical charges, there should be formed, in the first reaction, some phosphine and hypochlorous acid, and in the second, some nitrous acid and hydrochloric acid. In neither case does the alternate reaction take place. A study of many other types of reactions leads us to believe that the electrical charge on the atom is the guiding influence in the directing of reactions. As will be pointed out later, this electrical influence need only be

potential; that is, the atom may simply have the tendency to become electrically charged only under definite conditions.

Valence, defined by the Kossell-Thompson theory is the loss or gain of electrons. One electron lost develops a positive valence, while one electron gained develops a negative valence. Obviously, this theory finds its greater application among the inorganic compounds, although even there its application to all cases is not satisfactory. The very fact that there are other theories indicates that this particular one is inadequate for all cases.

The Bohr Theory.

Bohr (13) assumes that all valence electrons rotate in elliptical orbits of extreme thinness. When the electron is far out in its orbit it cannot be held firmly by the nucleus and therefore may be lost completely or partially by the atom. Fig. 3 illustrates the

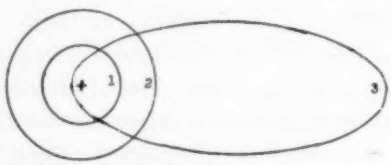


Fig. 3—A Modified Model of the Bohr Conception of the Hydrogen atom showing energy levels of High Stability (1 and 2) with Reference to the loss of the Electron and One Energy Level (3) of Low Stability.

Bohr conception of the hydrogen atom (an incomplete conception, since all of the possible orbits are not shown). When the electron is rotating in one of the inner circular orbits it cannot be lost; only when it has acquired enough energy to be transferred to the elliptical orbit can it be lost from the atom, this process being ionization. This, of course, postulates the addition of a definite amount of energy corresponding to the ionization potential.

Kharasch (7) has done some very interesting work along the line of valence as related to the various energy levels of the Bohr atom. This will be discussed later. (See page 23). For a positive valence of two, two electrons, which have occupied two elliptical orbits, will be lost, and for a valence of three, three electrons; for a valance of four, four electrons, etc. . . Negative valence is developed as the result of the gain of an electron by

the atom. This electron will rotate in some orbit of the atom gaining it, or more probably, in company with another electron, in any orbit at right angles to a line connecting the nuclei of the two atoms. (See Fig. 4.) (The hydrogen molecule.) From this

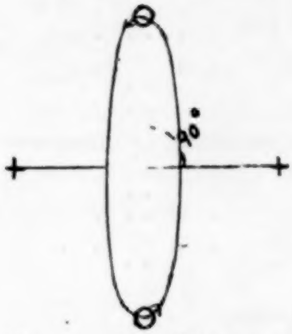


FIG. 4 — THE HYDROGEN MOLECULE.

it may be inferred that the electrons are held in common by both atoms, but the orbit may be closer to one atomic nucleus than the other. The atom closer to the electron pair has a negative charge, while the other atom has a positive charge.

The Bohr theory of valence correlates the development of valence with the physical properties of the atom, much more successfully than does the Kossell theory.

THE LEWIS-LANGMUIR THEORY.

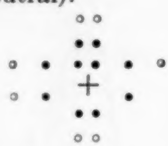
Lewis (12, 13) states that a chemical bond is established by two electrons being held in common by two atoms. This pair of electrons is held between the two atoms. Usually one electron is furnished by each atom, but in some cases both electrons may be furnished by the same atom. (See below, case of sulfuric acid.) Lewis deduced the pairing of electrons from a study of over one hundred thousand compounds, in nearly all of which the number of valence electrons (electrons in the outer shell) is even. The following cases will illustrate the Lewis conception of valence. (These illustrations are two dimensional: see reference 10 for three dimensional illustrations.) The Hydrogen molecule.

$$+ \overset{\circ}{\bullet} +$$

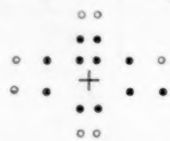
The solid and open circles will be used to designate the source of the electrons. In most cases this is not a matter of importance. However it is important where both electrons come from the

same atom. The type of bond composed of an electron from each atom is termed a *co-valence,* while the bond established by two electrons from the same atom is termed a *co-ordinate co-valence.*

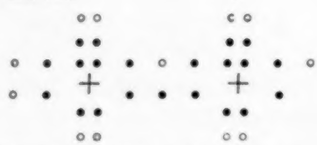
The chlorine atom (neutral).



The chlorine ion (negative). Corresponds to Cl

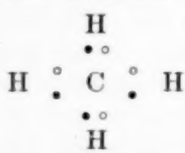


The chlorine molecule.



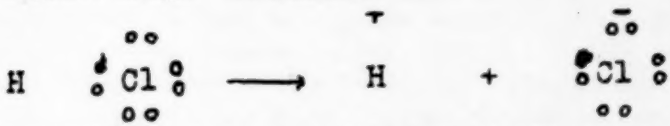
Stability is attained in the above case because the outer valence shells are completed, i.e., have eight electrons, two of which are held in common in the valence bond. In the case of the hydrogen molecule, stability is represented by a single pair of electrons.

Methane (only the valence electrons are shown.)



Methane represents the usual type of organic valence, in which no polarity (charge on atom) is exhibited, both atoms in fact being neutral, since neither has lost its electron. Each atom holds to its electron with approximately half of its former attachment force, and since the electron pair is situated in an orbit midway between the two nuclei, neither atom is positive or negative (polar). Sulfuric acid. (Only valence electrons are shown). The bonds 1 and 2 are of the co-ordinate co-valence type, while bonds 3 and 4 are of the normal co-valence type. Some recent work by Sugden has led to a partial revision of this formula.

Lewis explains the ionization of inorganic compounds as being due to the fact that one atom or radical retains or loses the electron pair. The ion or radical carrying the electron pair then has the negative charge. To illustrate:



Apparently the electron pair is very firmly attached to the chlorine atom in hydrochloric acid.

The Schroedinger Theory.

The concept of the Schroedinger atom (5, 15) being mathematical, it becomes difficult to outline a valence scheme for it. Apparently we must look to the older concepts of the loss or the gain of electrons as being synonymous to the loss or the gain of little "bundles" of energy, the nature and dimensions of which are defined by complex mathematical equations. It will be necessary to wait for some time before the valence concept of the Schroedinger atom is clarified sufficiently for general use. In fact it may be impossible for us to use this conception due to its mathematical intricacies.

Polar and Non-Polar Valence.

So much has been written regarding polar and non-polar valence or polar versus non-polar valence, that it seems desirable to attempt a correlation of these apparently different types. By polar is meant that type of valence which is definitely electrical and in which atoms show definite ionic tendencies (tendency to ionize) such as is the case with HCl, KCl and the great majority of the inorganic compounds. We might, in order to generalize, define polar valence as the valence of the inorganic compounds. Exceptions to this have been pointed out. By nonpolar is meant that type of valence which is not definitely electrical and which is most clearly that of the organic compound.

Polar valence has been defined as electrovalence, while non-polar valence is referred to as co-valence. In addition to these two distinct types there is a third and intermediate type, which we shall call the electro-co-valence type. Illustrations of these three types are given below.

Polar valence.

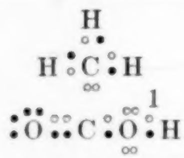
Case. HCl. Page 21

Non-polar valence.

Case. Methane. Page 20

Electro-co-valence.

Case. Acetic acid.



Electron pair 1 is held more closely by the oxygen atom than by the hydrogen atom, thus giving the oxygen a slight negative charge, and the opposite charge for the hydrogen. This electron pair is not held as firmly by the oxygen as is the electron pair of the case of hydrochloric acid, hence the much less negative charge, but it is held more firmly than is the case with the usual co-valence electron pair. From these reasons there arises the necessity for the intermediate type of valence bond, namely; the electro-co-valence type. This type is found in the case of most organic acids.

The type of valence (see above) apparently depends upon the relative position of the pair of electrons constituting the chemical bond, and may be represented as follows:

Polar	A: B
Non-polar	A : B
Electro-co-valence	A : B

where A and B represent the atomic nuclei. Kharasch (7) has pointed out that there may be gradations of valence all the way from polar to non-polar, and even gradations of the latter, as illustrated by the following:

(1) A : B
(2) A :B

Number 1 represents a polar union of slight stability (electron pair held only loosely by each atom), while number 2 represents a polar union of great stability (electron pair held firmly by both atoms). Rather strong experimental verification of the stability and instability of the polar bond has been obtained by Kharasch.

From the above presentation it can readily be seen that the difference in types of valence is more fancied than real. The polar bond may become non-polar or vice versa by the shifting of the position of the pair of electrons making up the bond. The bond between the atoms of hydrogen in the hydrogen molecule is undoubtedly non-polar, but by shifting the position of the pair of electrons from midway between the two atoms to a position nearer one, the bond becomes polar. This is a type of bond potentially polar, but actually non-polar. Theoretically, at least, all non-polar bonds are of this type, the ease with which the electron pair is shifted depending upon the force with which it is held by the two atoms involved. *The application of this shifting of electrons will result in the development of a polar, non-polar, or electro-co-valence, dependent in each case upon the relative position of the pair of electrons.*

Conclusion.

There is great need for a theory which will explain not only the mechanics of valence (why atoms hold together) but also why certain atoms join and others do not. The former has met with practically a full explanation, but only a little work has been done on the latter. Rodebush (6) has pointed out the relation of the electro-affinity (ability to hold electrons) to ionization potential, while Kharasch (7) has explained the stability of certain molecules on the basis of the location of the valence electrons in certain energy levels. London and Heitler (15) have been able to predict reactions between atoms on the basis of the new Schroedinger Wave atom and Pauli's Exclusion Principle. Both are too complex to be dealt with in this paper.

The writer has borrowed freely from any and all available sources of information, to which sources he desires to tender his thanks. No particular originality is claimed for any of the conceptions set forth in this paper.

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A NEW METHOD OF TESTING FOR BROMINE AND IODINE IN THE PRESENCE OF EACH OTHER.

DR. F. HARMS in *Zeitschrift fuer den Physikalischen und Chemischen Unterricht*, November-December, 1929.

In order to prove the presence of the two halogens, bromine and iodine, the iodine is usually displaced first by means of some chlorine water and is identified by shaking it with carbon disulphide or chloroform; then chlorine water is added in excess which oxidizes the iodine to iodic acid and displaces the bromine thereafter; this in turn is identified by shaking out with carbon disulphide or chloroform.

The use of chlorine is not pleasant for practical as well as for hygienic reasons. The following procedure offers decided advantages:

The substance to be tested is dissolved in water. To this solution a few drops of sodium hypochlorite solution is added. This displaces the iodine but not the bromine.

$$NaOCl + H_2O + 2KI = 2KOH + NaCl + I_2.$$

After the sodium hypochlorite solution has been added, shaking with chloroform will color the same violet if iodine is present; if the substance does not contain iodine the chloroform will remain colorless.

If iodine is detected, an excess of sodium hypochlorite solution is added. After further shaking the color of the chloroform will disappear because the iodine is oxidized to iodic acid thus:

$$I_2 + 5NaOCl + H_2O = 2HIO_3 + 5NaCl.$$

In order to show the presence of bromine also some sulphuric acid is added. This acid liberates bromine from bromides thus:

$$2KBr + H_2SO_4 + NaOCl = K_2SO_4 + NaCl + H_2O + Br_2.$$

If the substance contains a bromide, then chloroform shaken with it will be colored brown; if bromides are absent the chloroform remains colorless.—Translated by W. F. Roecker.

THE FIRST AMERICANS.

By Wilton Marion Krogman, Ph. D.,

Department of Anthropology, University of Chicago.

If the antiquity of Man in the western hemisphere were to be regarded as a straight line 200 feet long, then the present white occupants of the United States—"Americans"!—would find lodging on only the last three or four feet. Thus our war-cry of "100% American" becomes a national slogan impossible of realization because it is founded, not on history, but on an appeal to the sentiment of the masses.

The American Indian is an "Indian" by courtesy alone. Columbus, seeking a westward passage to India, the fabled land of spices and riches, named the dusky aborigines of this continent "Indians," for he thought he had discovered the land he sought. When the nature of his discovery became known, the position of the New World native was not an envious one. The Old World historians, monastically trained, denied the "Indian" inclusion among the races of Man, for he had not been mentioned in the Bible. As a result the natives were regarded as inferior, fit only to be enslaved. Not until the promulgation of a Papal Bull was the Indian dignified with the status of humankind. Needless to add, however, the enslavement continued.

The scholars of the 18th and 19th centuries were greatly puzzled as to the origin of the American Indian. Both on the basis of physical constitution and cultural achievement, the Indian was identified with virtually every one of the then known peoples: Babylonians, Phoenecians, Hittites, Welsh, Turanians, Scythians, Tamils of India, and most frequently of all, "Tartars" or the "Lost Tribes of Israel," It was only until a careful anthropological study was made of the Indian and his remains, both skeletal and cultural, that he was identified as belonging to the great Mongoloid division of Mankind.

The question arises as to the antiquity of the American Indian. When did he come, and by what route? We shall first consider the time of his arrival.

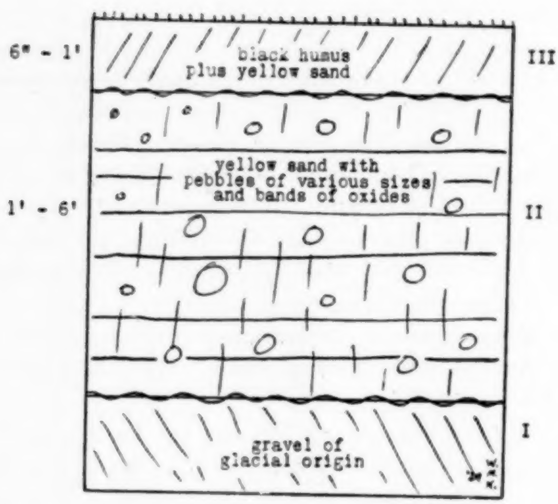
One of the most interesting theories of the origin of North American types is that which identifies the Eskimo as the successor of the Cro-Magnon people who migrated from Europe some 20,000 years ago. The Cro-Magnon skull found at Chancelade, in France, evinces the so-called "disharmonic face" found among the Eskimo, in which the great breadth of the face meas-

ured across the cheek-bones is disproportionate to the height of the face. The theory is an interesting one, but purports to account for the Eskimo type alone.

The entire western continent has produced no skeletal material of an undisputed geologic age greater than approximately 10,000 years. The Lagoa Santa skulls, found in Brazil in 1835-44 by P. W. Lund, a Swedish explorer, were associated with extinct mammalian forms, but there was no adequate proof of contemporaneity. The Calaveras skull, found in a mine shaft in California in 1866, at a depth of 130 feet, beneath seven layers of alternate gravel and lava, is of the same physical type as the American Indians and probably was the result of a hoax. The Lansing skeleton, found in Kansas in 1902 at a depth of 20 feet in a loess deposit, is not of geologic import since the formation is of relatively recent origin. The foregoing are but typical of a class of "prehistoric," "preglacial," "diluvial," "early man," finds of skeletal material all of which offer evidence of a physical type differing very little from that of the modern types. The Indian, then, has not evolved on this continent.

FIGURE I

SCHEME OF TRENTON GRAVELS



I - "Paleolithic"
II - Rude culture characterized by chipped blades and hammerstones. ("Argillite culture")
III - Modern Delaware Indian.

A different type of evidence, however, is that offered by the direct testimony of Geology and Paleontology. North America has been subjected to a series of four glaciations, the last of which, the Wisconsin, occurred some 20,000 years ago, with a Jerseyan substage of about 10,000 years ago. At Trenton, New Jersey, there has been found in association with the glacial gravels of the substage, crude "implements," apparently the handiwork of human beings. The implements, consisting of rude blades and hammerstones, are made of argillite, after which the stratum receives the term "Argillite culture." (See Fig. I) The evidence here points to an antiquity of at least 10,000 years with a maximum of an indicated 20,000.

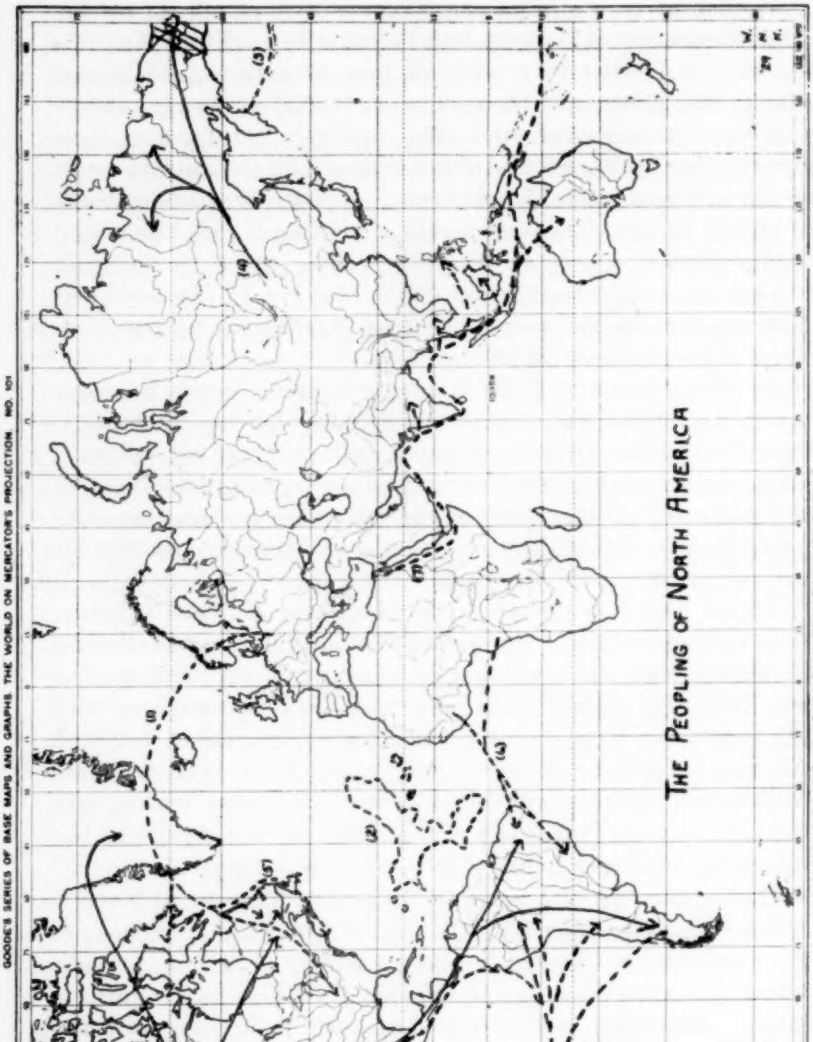
In 1895 a member of the Kansas geological survey found an arrowhead in association with the remains of *Bison occidentalis*, an extinct form. This was repeated again in Texas several years later. At about the same time evidence was presented indicating the possibility of the bones of the mammoth having been subjected to fire. All of these statements, by their very nature, did not permit of proof.

Within the last ten years investigations at Vero, Florida, have proved without a doubt that Man in America was contemporaneous with the mastodon and mammoth. As indicated in Fig. II human remains have been found *in situ*, associated with the remains of these animals which have been extinct in North America for at least 20,000-25,000 years. There is an alternate explanation that the animals may have, for some reason, persisted locally, so that it is not a question of Man's priority but rather the local persistence of forms elsewhere extinct.

During the past two years the American Museum of Natural History, in cooperation with the Department of Anthropology of the University of Chicago, has been studying at Folsom, Arizona, where arrowheads are found associated with an extinct form of Bison. The time here indicated is quite in keeping with the antiquity established at the Vero site.

We may turn now to the consideration of the route by which Man entered the western hemisphere. There are as many theories as there are theorists, and on the accompanying map I have graphically indicated some of the foremost. They fall into two classes: the first considering the route of incoming Man; the second explaining the origin of cultural elements.

The northeastern route (1) has been advanced by adherents of the continent of Holarctica, affording a land-bridge from north-


GOODE'S SERIES OF BASE MAPS AND GRAPHS. THE WORLD ON MERCATOR'S PROJECTION. NO. 101
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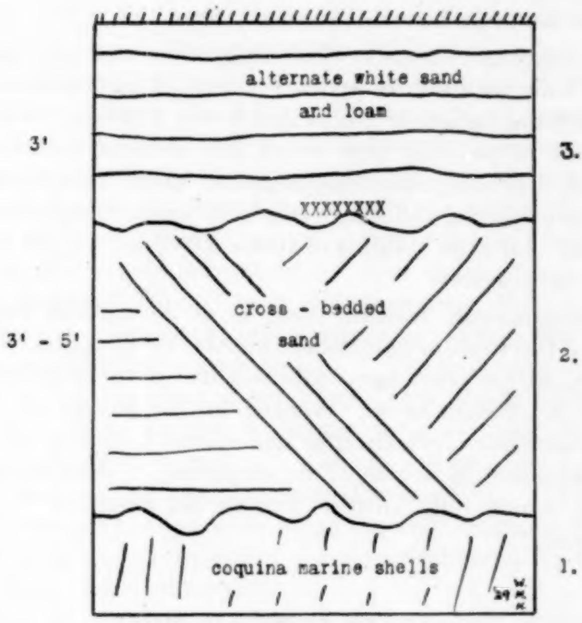
ern Europe. The southern route (2) is based on the famed "lost continent of Atlantis." There are two northwestern routes: the Aleutian Islands (3) and the Behring Straits (4). The first three routes named are unsound geologically, though, as indicated by the perpendicular lines on the map, the U. S. Geodetic survey has revealed a shallow area at the eastern end of the Aleutian chain.

FIGURE II.

SCHEMATIC CROSS-SECTION, VERO, FLORIDA



1 and 2 are Early Ice Age.

3 is post-glacial.

XXXXX - location of human remains with those of mammoth and mastodon.

The Behring Straits route (4) is almost certainly the path chosen by Man as he entered North America. As indicated by the solid line (in contrast to the dotted lines which imply more theoretical assertions) the American Indian diverged from a parent stock which in Asia gave rise to the Asiatic Mongoloids,

and in the western hemisphere the Eskimo and the Indians of North, Central, and South America.

With respect to cultural contributions we note the problem of Norse contact (5) about 1000 A. D., the assertion of African influence (6), of Egyptian influence (7) via a world-wide "Heliolithic wave" about 900 B. C., and direct contact from Polynesia (8). These theories are based on the possibility of the infiltration, especially in South America, of more or less random cultural contacts, achieved by the drift of ocean currents sweeping onto the western and eastern coasts of this continent. At best the contacts have been so slight as to leave very little trace in the civilization of prehistoric America.

Our problem of relative chronology must also take cognizance of the time required for sporadic bursts of immigrants to reach the far-flung corners of North and South America; for the differentiation of physical type which has occurred; for the rise of great civilizations, embracing linguistic specialization, the domestication of plants, and a high degree of material and social development. Like the building of Rome, all of this cannot have been achieved in a day.

The American Indian, then, is of Mongoloid origin, and entered the western hemisphere via the Behring Straits approximately 20,000 years ago. His is a history of dignified human progress. Before he was crushed by the advent of the white man and white civilization he had attained, by his own industry and initiative, a degree of development, a civilization, if you please, which fully entitles him to his claim as—"The First American"!

USE OF COPPER IN SHIPS.

A modern 30,000 ton ship may be as much as one-tenth copper represented by 6,000,000 pounds of copper installations if all appropriate parts were copper. The bronze propellers may contain 53,500 pounds of copper, shaft sleeves 53,000 pounds, main propelling machinery 200,000 pounds, electrical gear and wiring 3,000,000 pounds, and even such inconspicuous installations as voice tubes may require 100,000 pounds of copper.

Sea chests are an integral part of the hull. These are of bronze and in a large ship will weigh 300,000 pounds or more. In a ship such as the "Leviathan" the copper alloys used in the direct driven turbines amount to over 5,000,000 pounds.

The requirements of magnetic compasses demand the use of nonmagnetic, non-rusting metals. Non-magnetic and finishing plating in a large ship will account for 100,000 pounds of copper.

MATHEMATICS AND ESTHETICS.*

By Nathan Altshiller-Court,
University of Oklahoma, Norman, Okla.

A lady of my acquaintance, a very cultured person with literary proclivities, asked me once whether mathematicians see beauty in their science. During her school career she has heard her teacher of mathematics, whose subject, by the way, she enjoyed very little, refer to a theorem as being beautiful, and this statement seemed to her very preposterous. I do not remember in what words I replied to her question. But I could have quoted those masters of thought who spoke eloquently on the subject. Henri Poincaré (1854-1912), one of the greatest minds of all times, said in this connection: "Above all, adepts find in mathematics delights analogous to those that painting and music give. They admire the delicate harmony of numbers and of forms; they are amazed when a new discovery discloses to them an unlooked for perspective, and the joy they thus experience has it not the esthetic character, although the senses take no part in it? Only the privileged few are called to enjoy it fully, but is it not so with all the noblest arts?" Our distinguished contemporary Bertrand Russell said: "Mathematics, rightly viewed, possesses not only truth, but supreme beauty—a beauty cold and austere, like that of sculpture . . . The true spirit of delight, the exaltation, the sense of being more than a man which is the touchstone of the highest excellence, is to be found in mathematics as surely as in poetry." Let me add just one more quotation, this time from an American, Thomas Hill. "The mathematics is usually considered as being the very antipodes of poesy. Yet mathesis and poesy are of the closest kindred, for they are both works of imagination."

For the initiate mathematics has very much in common with the fine arts. On the other hand the fine arts are greatly indebted to mathematics. To achieve verse rhythm the poet must *count* the feet in his lines, i. e. the regularly recurring *metrical units.* The words in a verse must be placed in *measured* and cadenced formation so as to produce a metrical effect.

The rôle of mathematics in music is a far more intimate one. Several centuries before our present era Pythagoras observed already that when musical strings of equal length are stretched

*Doctor Court is well known for his researches in geometry. In the field of modern geometry his book *College Geometry* is a pioneer work. He has been a frequent contributor to the "Problem Department" of School Science and Mathematics. This article first appeared in the Sooner Magazine.—D. R.

by weights having the proportions of ½, ⅔, ¾, they produce intervals which are an octave, a fifth, and a fourth. Ever since that time mathematicians have greatly contributed towards the elaboration of the theory of music. Euclid, the author of the famous Elements, wrote two books on the theory of music. When the music of the ancients, the homophonic music, gave way to the polyphonic music of the middle ages, mathematicians have furthered its theoretical development. The Renaissance has witnessed the birth of our modern, harmonic music, and among those who contributed towards the study of its theory we find such names as Kepler, Descartes, Huygens.

The close connection between mathematics and music has been expressed by Helmholtz as follows: "Mathematics and music, the most sharply contrasted fields of scientific activity, and yet related, supporting each other, as if to show forth the secret connection which ties together all the activities of the mind, and which leads to surmise that the manifestations of the artist's genius are but unconscious expressions of a mysteriously acting rationality." Leibnitz is even more specific. "Music is a hidden exercise in arithmetic, of a mind unconscious of dealing with numbers." The love of mathematicians for music is a well established fact. The great contemporary mathematical genius Albert Einstein is an excellent violinist.

Sculpture, architecture, painting, and the graphic arts in general, obviously involve geometric considerations. What geometric constructions artists have used, consciously or unconsciously, to achieve their esthetic effects has been well analysed and put clearly into evidence. The lack of space does not allow me to enlarge upon this very interesting subject. I shall simply mention that one of the most telling esthetic effects is obtained by the so-called "Golden Section" and its derivatives, and this section is connected with the quadratic equation $x^2-ax = a^2$. Those interested in this subject may consult (1) Jay Hambridge, *Dynamic symmetry;* (2) L. D. Caskey, *Geometry of the Greek vases;* (3) Matila C. Ghyka, *Esthétique des proportions dans la nature et dans les arts.* It is far from being a mere coincidence that great artists like Leonardo da Vinci, Raphael, Michael Angelo, and Albert Durer felt a very great attraction for mathematics. The great accumulation of knowledge of our own day makes such manifestations more rare.

If you, dear reader, do not belong to the fortunate few who can discern beauty in mathematics, you may still learn to perceive mathematics in beauty.

THE PART OF SCIENCE IN THE FINDING OF PETROLEUM.*

By Chas. N. Gould,

Director Oklahoma Geological Survey, Norman, Okla.

PART I.

As you drive your car down the streets of your home town, I wonder if you ever think of the debt of gratitude that you owe to some lone geologist who, ten years before, tramped the hills of Oklahoma or Texas or California. It *is* a far cry from an Oklahoma geologist tracing rock ledges over the hills to a motor car on the city street a thousand miles away. In this series of articles, I will attempt to show how not only the car owner but also everyone throughout the Nation and the civilized world who uses motor fuel is largely dependent on the geologist and other scientists.

Petroleum, or rock oil, occurs in the stratified rocks of the earth's crust, and is found all the way from the surface down to the deepest point to which the drill has yet penetrated. Oil seeps and springs occur in many parts of the earth. In America, on Seneca Indian Reservation in New York State, oil from springs was collected by Indians and used as medicine long before the advent of the white man.

The Deepest Well.

As a usual thing, however, petroleum is produced not from springs but from wells, and these wells vary from less than 100 feet to several thousand feet in depth. Ten years ago the deepest well in the world, somewhere between seven and eight thousand feet deep, was in West Virginia. Later a well in California was drilled to a depth of more than 8,000 feet, and this well produced a small amount of oil. Within the past year, however, the deepest well in the world has been drilled in the Big Lake field, Reagan County, west Texas. This well is 8,523 feet deep and at last reports was producing more than 2,500 barrels a day of very high-grade oil. The oil from this well is so pure that it can be run directly from the well and used as fuel in motor cars.

Four Essentials for an Oil Field.

Long experience by thousands of investigators, in many lands, has demonstrated that, in order for oil or gas to be found

*Part of a paper read before section E, geology and geography, American Association for the Advancement of Science, Des Moines, Dec. 30, 1929. The remaining parts of the paper will appear in later numbers of School Science and Mathematics.

in commercial quantities at any particular place, at least four essentials exist. These essentials are: 1st, source of supply; 2nd, reservoir rock; 3d, cap rock; 4th, some form of geological structure.

Origin of Oil.

One of the first questions that the geologist is asked is this: How is oil formed? And I think that the best answer to the question is: No one knows.

For many years scientists in many lines, geologists, chemists, and physicists, have been working on this problem, and many theories to account for petroleum genesis have been formulated. Of these various theories, the two most common may be called the *inorganic* theory and the *organic* theory. It is not easy to state in a sentence or two the gist of these rather complicated theories which really require whole pages for their exposition, but I shall attempt to do so.

The inorganic theory postulates that oil and gas have been formed deep in the earth by the action of very hot water on the carbides of certain of the metals, much as we use water with calcium carbide to produce acetylene gas. The chemist has even gone into the laboratory and in this manner has formed inorganically a substance which in many ways is analogous to petroleum. It may be possible that nature in her underground laboratory is doing the same thing, and that part, at least, of our petroleum has been formed inorganically.

At the present time, however, I think I am safe in saying that 90 percent, possibly 99 percent, of the working chemists, geologists, and physicists throughout the world who have given the matter thought, and are qualified to speak with authority, believe that oil and gas have been formed organically within the earth. That is to say, we now believe that the various organisms, plants and animals, mostly minute forms, which were buried in the ooze and mud laid down in the far-gone, prehistoric oceans, have given up their organic parts which, by long-continued, natural distillation, have formed petroleum. Fossil remains of these various plants and animals are found today in the rocks, but these fossils are usually only the impressions or skeletons of the orginal organisms. According to this theory, the live part of the plant or animal has gone to make petroleum.

However, if we accept the organic theory to account for the origin of petroleum and natural gas, another difficulty imme-

diately confronts us. Was the ultimate source of these materials plant life or animal life? Geologists and chemists are still divided into two hostile camps in this matter, each contending valiantly for its own particular ideas. A few years ago most of us believed that we must look to animal remains for the source of petroleum. But as time has gone on, and more and more studies have been made by competent men, the pendulum seems to have swung in the other extreme. At the present time the concensus of opinion among scientific men seems to be that plants and not animals were the chief sources of petroleum. An exponent of this theory, David White, the famous plant paleontologist of the United States Geological Survey, believes that the chief sources of petroleum must be sought in the waxy and resinous parts of seaweeds and other marine plants which grew in prehistoric times and were buried in the rocks.

Reservoir Rock.

The second essential is a reservoir rock, by which we mean simply some porous stratum or a rock with small pores, openings, or interstices of such a character that it will serve as a catchment basin in which the oil may accumulate. In general, this porous rock is a sandstone or, in the parlance of the oil man, an "oil sand." Sometimes, however, it is a porous limestone, a shale, or a conglomerate, or it may be some other form of rock. The essential thing is the matter of porosity of the rock. There is no virtue in any rock *per se*. A sandstone, or other rock, that contains oil is an "oil sand," and conversely any rock that does not contain oil is *not* an "oil sand."

Cap Rock.

The third essential is a cap rock, or some dense, fine-grained formation lying above the "oil sand," that will retain the oil, hold it down, and prevent its escape. The cap rock is usually a dense, fine-grained shale, although it may be a dolomite, a dense limestone, or some other form of impervious rock.

The fourth essential, and the one which is the chief thing sought by the geologist in his search for oil, is some form of *structure*. In order to make plain what I am about to say, it will be necessary for me at this point to go a short distance afield, and attempt to explain very briefly some geological terms.

Geologists believe that all stratified rocks, the three most

common forms of which are limestones, sandstones, and shales, were laid down approximately level in the bottom of prehistoric oceans. The foundation stone of the science of geology is this statement, "All land has been formed under water." As you have ridden on the train in a mountainous country you have doubtless seen from the car window ledges of limestone and sandstone in the railroad cuts and along the sides of the hills, usually dipping at an angle, but sometimes lying level. These beds were originally deposited practically level on the ocean bottom; limestones, sandstones, and shales, in alternating sequence, one above another. Often these beds approximate many thousands of feet in thickness. After long ages these beds were raised above the ocean, and the country became dry land. Very often in the process of elevation from the ocean, the sediments were squeezed together and tilted. Just how this was accomplished does not concern us at the present time. But what I want to emphasize is the fact that in the process of squeezing, the various ledges were thrown into a great series of waves, washboard fashion. The arches, or up-shoved parts, we call *anticlines.* The troughs, or down-folded parts, we call *synclines.* These anticlines and synclines are of various sizes, varying from a few inches across to sometimes hundreds or even thousands of miles. The axes of the anticlines and synclines sometimes extend on the surface for long distances. A short anticline, where the rocks dip in all directions from a given point, we call a dome. A short syncline is a basin. A basin is shaped something like a saucer or butter bowl, but if the saucer or butter bowl is inverted it will form a dome.

It is this form of structure that is the fourth and in many ways the most important factor in the accumulation of petroleum. Oil and gas, being volatile substances, lighter than water, tend to ascend to the highest point in the rocks in which they are contained. In general, anticlines or domes are the structures most likely to contain oil, and experience has shown that perhaps 90 percent of the producing oil fields are located on structures of this kind.

Find the Bottle.

The behavior of oil and gas underground can perhaps be best illustrated by the example of a bottle partly filled with oil and water. Let us take an ordinary bottle and pour into it water and oil in approximately equal parts, filling the bottle about two-thirds full, leaving about one-third filled with air, which

is a gas. If we cork the bottle tightly, agitate it violently, and then let it come to rest, the three substances in the bottle, water, oil, and air, will arrange themselves in the order of their specific gravities. Water, the heaviest of the three substances, will go to the bottom. The lightest substance, air, will go to the top, and the oil, which is lighter than water and heavier than air, will invariably find its place in the middle of the bottle above the water and below the air.

And this is exactly what is happening in the rocks under an anticline or a dome. If a ledge of porous sandstone forming a suitable reservoir rock lies beneath a bed of impervious shale, which is the cap rock, and the rocks have been arched up forming an anticline or a dome, and if the three substances, oil, gas, and water, which usually occur in this porous sandstone, are present, they will naturally arrange themselves in the order of their specific gravities. That is to say, the gas will be found at the crown or the apex of the anticline or dome, the water will be found in the trough or syncline, and the oil will accumulate along the slopes of the anticline on either side of the gas and between the gas and the water.

This, in brief, is the whole theory of oil accumulation. What the geologists and other scientists are trying to do is simply to find the bottle underneath the surface which contains these three substances.

It is like the old game of our childhood, "Button, button, who's got the button." It is simply a question of "bottle, bottle, where is the bottle." In a later paper I shall endeavor to outline the different methods used by various kinds of scientists, geologists, paleontologists, chemists, engineers, physicists, and others in the attempt to locate new reservoirs of oil and gas—new "bottles" beneath the surface.

But How Find the Anticline?

The location of underground "bottles," in other words subsurface structures that may possibly contain oil or gas, is by no means an easy matter. Sometimes these structures may show on the surface, but more often they do not. Let me use another homely illustration. Suppose I have before me an ordinary dining room table covered by a cloth. If I were to ask you to turn your back and I were to slip a small silver coin under the cloth, and I were then to hand you a pencil and ask you to stab down and hit this coin concealed under the cloth, what chance

would you have of hitting it the first time? Perhaps one chance in fifty. And this is just about the chance the oil man will have of striking production without any surface indications or other scientific reasons for drilling a well in any particular place.

Suppose, however, that I slip under the cloth an inverted saucer which might represent a dome. You would perhaps have no difficulty in noting where the cloth is raised and you probably could hit the saucer the first time. This inverted saucer under the cloth might represent a well-marked surface structure.

If, however, instead of the coin or saucer I slip under the cloth a small lead pencil, which might represent a small anticline, you would have difficulty in hitting the lead pencil; but if, instead of a lead pencil, I were to use a rolling pin, which might represent a large anticline, you could locate the rolling pin without difficulty.

These homely illustrations, the coin and the inverted saucer which represent small and large domes and the pencil and rolling pin representing small and large anticlines, will show what I am trying to get at. The geologists or other scientists are simply trying by various methods and means, which I hope to discuss in later papers, to locate the various forms of structures, some of which show easily on the surface but many of which do not.

LABORATORY METHODS AND EXPERIMENTS IN PHYSICS.*

By H. C. Krenerick, *Milwaukee, Wis.*

To have perfect correlation between classroom and laboratory work, it is necessary at least in the majority of experiments, to have the laboratory sufficiently equipped that all students may work on the same experiment, individually or in small groups. The cost of such equipment is not prohibitive in the great majority of schools today.

I have no patience with those individuals who claim that the laboratory is not necessary, that the lecture-demonstration method better prepares the student and give as their proof that the student can write a better examination. I would be very much surprised if he could not, for with that method much more time must be available for drill and problem work. Why not be consistent and omit the demonstration? With the extra time in drill he would be able to write a still better examination.

I am not at all interested in that controversy. Its solution is simple. It is purely a question of why we are teaching physics. If it is to acquire a certain number of scientific facts, use the lecture-demonstration method. Physics with its laboratory possibilities offers to the student a type of information and experience which is of far more value to him than the ability to write a good examination, a training not found in any other subject. These tests that are being made in the lecture-demonstration method do not and can not prove anything because they test only the lecture-demonstration class of accomplishments.

*Extracts from a paper read before the Physics Section of the Central Association of Science and Mathematics Teachers, Chicago, Nov. 29, 1929.

UTILIZING THE NATURAL INTERESTS OF PUPILS IN TEACHING BIOLOGY.

By O. D. Frank,

School of Education, University of Chicago.

Boys and girls are naturally a good many things. They are natural eaters, climbers, players, collectors, tellers, imitators. Normal children are hearty, healthy, happy, hungry, inquisitive, jubilant optimists who ask only to be given an opportunity for self expression.

Just as nature has given each leaf, bud, blossom, and blade of grass a desire to find its place in the sun, so she has put into the soul, mind, hands, and heart of every real boy and girl a desire to be himself or herself to the fullest.

Taking these natural tendencies, interests, and instincts on the bound, we as teachers are given wonderful "hooks of steel" for grasping and guiding children on to their highest possible development physically, mentally, and socially.

The following devices have been found helpful in teaching nature-study and biology. They were designed with the natural interests of boys and girls in mind.

Original Devices for Teaching Natural Science.

"Beto" Books.

Each pupil provides himself with a small note book in which he places his best thoughts pertaining to biology. Only one thought may be recorded in the little book each week.

The word "Beto" signifies Biological experiences, thoughts and observations.

The "Beto Book" is the pass by which the pupils gain entrance to the classroom on Friday. The "passes" are collected at the door by the "Beto" secretary; they are arranged in alphabetic order and placed on the teacher's desk.

The books are marked as follows: a check is placed to the left of all "Betos" that contain grammatical mistakes or that are written in a slovenly manner. "Betos" that show lack of careful thinking or that are not biological in their character are also marked with a check. An S is placed before carefully thought-out scientific "Betos." Unusually clear, original, scientific "Betos" receive the mark of SS.

The books are returned to the Secretary on Monday. After checking the marks received, the Secretary returns the books to the pupils.

On the last Friday of each month the class hour is devoted to a round table discussion of "Betos." The pupils look forward to this hour with keen delight.

Animal Tracks.

Obtain small fairly strong paste board boxes or cigar boxes or small boxes can be made in the manual training shop. Place modeling clay or common red or yellow clay in the bottom of the boxes. The surface of the clay should be very smooth. Permit an animal to walk on the clay or take its foot and make an imprint on the clay.

Tracks of mice, rats, cats, dogs, pigs, sheep, goats, calves, ponies, guinea pigs, turkeys, chickens, ducks, geese, frogs, toads, turtles, alligators, and baby brother or sister can be recorded in the clay.

Tracks are attractive and this little stunt provides a very merry way

of becoming acquainted with the "understandings" of animals.

The Annual Growth of Trees.

The purpose of this field trip will be to make a comparative study of the annual growth of five different kinds of trees. Prepare a chart as follows:

Name of Tree	Year	Growth in Inches					
		North	East	South	West	Total	Av.
	1929						
	1928						
	1927						
	1926						
	1925						
	Total						

Prepare graphs to show as many facts as possible concerning the growth of the trees you have studied.

Consult weather charts for the years 1925-1929 and set down any facts that explain the rate of growth of the trees as shown by your data and graphs.

"How Do You Do" Field Trips.

Before one can really know and appreciate the "Big Out of Doors" he must meet and study the plants, animals, rocks, stars and other things in their natural settings. With this thought in mind you will be conducted on a number of field excursions. During these trips you will be introduced to various phases of nature.

On the first trip we will say "How Do You Do" to the trees. Interesting facts pertaining to each tree will be pointed out which will enable you to recognize the tree when you meet it again. It will be well to set down the "ear marks" of each tree in your note book as they are pointed out to you. On our second trip we will examine a number of trees to see if we recognize our friends to whom we have said "How Do You Do."

The following are additional field studies that will be made from time time:

Common herbaceous plants growing near our school.
What bird is that?
Who's who in the zoo?
The six-legged tribe.
Plants cows won't eat.
Fungi the funny "guy."
Lake Michigan pebbles.
The northern constellations.

Insect Life-Histories.

Collect the eggs, larve in various stages of development and the adult insects. Mount them in glass tubing as follows: seal one end of the tube with sealing wax or by heating the end of the tube. Place the eggs in the bottom of the tube and pour in some alcohol or formaldehyde (5% solution.) With a smaller glass tube or stick push a piece of cork or corn pith down into the tube near the eggs. Now place the smallest larva you can find in the tube with a second piece of cork over it. Continue until you have a complete life history. Seal the upper end of the tube with sealing wax. Small numbers should be pasted opposite each specimen in the tube and the descriptive data placed on a card.

When several life-histories have been prepared, it is well to build a stand to hold them. For the stand you will need two pieces of soft wood

14 inches long. One of these pieces of wood should be 1 inch wide and ½ inch thick, and the other should be 4 inches wide and 1 inch thick. Bore 14 holes one inch apart in the 14x1x½ board. These holes should be a little larger than the diameter of the glass tubing. In the second piece of wood countersink 14 holes one half inch in depth one inch apart. You now have the top and base of your stand. Prepare two pieces of wood one inch square and about one inch shorter than the length of tubes in which you have placed your insect life histories. These are the uprights for the stand. Sand paper the four pieces of wood and fasten them together with nails or screws. When painted this is a very attractive device for displaying insects life histories.

Note:—Other "Original Devices" will appear in future issues of SCHOOL SCIENCE AND MATHEMATICS.

IS HIGH SCHOOL MATHEMATICS AN ADEQUATE PREPARATION FOR HIGH SCHOOL PHYSICS?

BY JEROME G. LEMMER,
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That Physics is a bugbear for most High School students—of the college students I do not speak, although the same may be true of them—everyone will probably agree. As to the reasons for the fear of the subject there are many explanations. As the title of this paper indicates I am treating of the mathematical reasons for the dislike of the subject.

As a teacher of Physics it did not take me very long to learn that there was a very general fear of the subject, and, naturally, I began to ask the question: "Why?" I had long considered the mathematical inability of the boys to be one of the principal difficulties, and it was while harboring thoughts of this kind that I happened on something that I thought might have interesting results, and it did. That "something" was called "An Inventory Test for the Mathematics Needed in High School Physics." It was, I think, the result of an investigation made in preparation for a Doctor of Philosophy degree in Education by L. R. Kilzer, then of the University of Iowa, in collaboration with Dr. T. J. Kirby of the same University. Three purposes of the test were indicated, only the first of which interests us, viz., "To point out to Mathematics teachers those items in their subjects which are useful in High School Physics, and to provide means for testing the pupils on these same items." After an examination of the test and with the approbation of the Principal I decided to give the test to the entire class of Third Year High, most of whom will be taking Physics this fall. The results were most interesting.

The test is made up of two parts, part one containing 66 questions on Arithmetic and Algebra, and part two 23 questions on Geometry with one very simple question on Trigonometry. The test was compiled by working all the problems in five commonly used text-books, together with their laboratory manuals, and using all the correct methods that a pupil would be expected to use. The processes were recorded and from these the test was built up.

All the boys of the Third High Class, 77 in all, took the test. Of these 77, averaging both parts of the test together, only 12 received 70% or over. The highest score attained was 86.6%, the lowest, 18.8%. The median was 48.8%. In part one alone, Arithmetic and Algebra, the highest score received was 87.8%, the lowest, 19.7%. The median was 47%. In part two, Geometry, the highest score was 95.8%, the lowest, 16.7%. The median was 54.2%. I counted as incorrectly answered those which the pupil had not done, even those which he had failed to get from a lack of time. These two facts may account for the failure of the class to reach the tentative medians of the test, which were 60% for the test as a whole, 56.6% for part one, and 70.8% for part two.

On the basis of this test and my own little experience as a teacher, I answer the question "Is High School Mathematics an Adequate Preparation for High School Physics?" in the affirmative, but I hasten to add a qualifying clause, "if the pupil knows his High School mathematics." And the question immediately arises: "Does he?" and I answer: "In many cases"—I almost said in most—"he does not." Why doesn't he?

The results of the test would seem to show that weakness in Arithmetic is one of the causes. A boy who is at sea in Arithmetic is certainly going to be at sea in Algebra. 16 boys could not find the value of 40^2, 25 could not find the square root of 16/25, 25 could not explain how to find the average of four numbers, to say nothing of 28 (all out of 77) who gave such answers among others as 1/8, 8, 4, and 18 for the value of 1^8, and the 65 who could not simplify $4/{}^7/_2$.

The Algebra in the test embraced nothing that could not be given to a high school class that had finished the subject matter of first year, but it showed the boys to be woefully weak. Simple linear equations are proven to be very difficult for the pupils, while simple fractional equations are almost impossible, as for example, "if $\frac{1}{2}at^2=2s$, to find t^2" which 74 out of 77 failed to

get, and the following problem which 72 failed to answer correctly or did not answer at all. "$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$. If p equals 18, and f equals 1.8, find the value of q." Here some allowance perhaps should have been made for many did not finish the test and the questions cited were found toward the end of the test, but the test would have been finished in the required time if the boys had known their matter, and even with all allowances made, the results of the test would still be poor enough to show a decided weakness.

I ought also to add that the poor results are not to be attributed to a poor class. As a whole the class which took the test was a representative one. There were more honor men (85% or over for a general average) than in any one of the other classes of the High School, and some of the men were exceptional. It is an interesting fact too, that the boy who attained the highest average in the classical course stood 33rd in the test, which would show that mathematics is a weak subject for him, and all the more so for many others. A word more about this later.

The Geometry was much more consoling in its results. I considered it the harder of the two tests but the results were better even though 53 (out of 77) did fail to get this problem: "If the hypotenuse of a right angle triangle is 10 ft., and one leg is 8 ft., what is the length of the other leg?"

In going over the results of the test some very enlightening facts were brought to light. Taking the test as a whole, of the 12 boys who received 70 or over, 10 were boys of the so-called scientific course, that is, had had some mathematics beyond first year Algebra and Plane Geometry. In part one of the test, Algebra and Arithmetic, 6 out of 7 who received 70 or over were boys who had taken Algebra III. In the Geometry test the results were about equal for the scientific and non-scientific men. No Solid Geometry entered into the test.

Would I infer from this that the scientific men were better students? I think not. Their superiority over the non-scientific pupils can, I think, be attributed to the fact that in Algebra III they have to repeat so much of their first year Algebra and it is so emphasized that at last it sinks in. The equality in the Geometry test can be accounted for by the fact that most of the boys had taken the subject just the year previous.

Mathematics is a subject in which most boys can and will get very interested if you only try to get them interested, and once you have them interested they will become more and more so. Why not then bring them to this happy state of mind? Apart from the mind-training qualities of mathematics there is the utility of the subject to be considered. One example, Physics, the bugbear, becomes Physics, the pleasure, but it will certainly never become that without the mathematics, and given the mathematics, the teacher of Physics will be better able to cover his matter, for he will not have to take time to teach mathematics that should already have been learned. But do the boys need more than the ordinary course, that is one year of Algebra and one year of Geometry? If the subjects have been well taught and the boys have put forth a little effort it is my opinion that the ordinary course is sufficient.

A CHEMISTRY STUDY OUTLINE.

By C. M. Haag,

Uniontown Senior High School, Uniontown, Pa.

The Chemistry Study Outline given below, if placed in the hands of the student, will give him a definite objective for which to strive. The student will be able to know what is expected, because too often he does not know how to distinguish between the essential and non-essential. Even in asking a student to distinguish between physical and chemical properties of a single element such as oxygen or hydrogen, the outline at once sets before him the fact that certain physical properties can be looked for, likewise certain chemical properties may be expected.

The outline is in as simple and abbreviated a form as can easily be placed on a single sheet, and yet so adjusted as to be used in the study of most elements and compounds as met with in the study of first year Chemistry. Space is alloted for the student to write his outline of facts for the substance to be studied. Some teachers may feel that emphasis should be placed on facts not here included, but probably those can best be taken care of as the occasion demands. The thing to bear in mind is, that the student has a definite goal to work for.

Chemistry Study Outline.

....Name

....Subject

....Common Name

I. Occurrence:

1..Free, or in what form.

2..Where.
3..Source of commercial supply.
4..Relative abundance, cheap, or costly.
5..

II. Preparation:
1..Equation or method of prep.
....
....
....
2..Best method of prep.
3..Why is 2 the best prep.
4..How purify prepared substance.

III. Physical Properties:
1..*Gas, †Liquid, Non-metal.
*† 1..Color.
*† 2..Odor.
*† 3..Taste.
*† 4..Weight.
*† 5..Solubility.
* 6..Liquefaction.
† 7..Sp. Gr.
8..Shape of crystal.
* 9..Exposed to air.
† 10..Solidification.
11..
12..

2. Metal:
1..Color.
2..Lustre.
3..Melting point
4..Vaporization point.
5..Conductivity of heat.
6..Conductivity of electricity.
7..Sp. Gr.
8..Malleability, tenacity, hardness.
9..
10..
11..

IV. Chemical Properties:
1. Combustion, oxidation,
1 + ...Equation for combination with air (O_2), or other gases.
2..To what does it support combustion
2. If substance studied is a compound:
1..Ionization equation
2 +heat ....Effect of heating, Indicate if reversible.
3..Equation for electrolysis and how
3. General reaction with other substances:
....
....
....
....
....

V. Uses:
1..Laboratory.
2..Industrial uses.
VI. Test for................
VII. Terminology, new term, definitions, laws, formulae:
....

BACKGROUND AND FOREGROUND OF GENERAL SCIENCE.

No. VII. ELECTRICITY.

By Wm. T. Skilling,
State Teachers' College, San Diego, Calif.

The historical approach to a subject is often the best approach. It usually leads one through the simpler phases of the topic, and it possesses the additional merit of making it a human interest story.

By testing such substances as glass and hard rubber combs rubbed with silk and wool children may get the same manifestations that were known in antiquity. A natural problem is to discover what pairs of substances rubbed together on a dry cold day will develop most electricity as measured by its ability to pick up bits of tissue paper.

If sparks can be seen and a crackling sound heard on combing one's hair in the dark it will help to identify such electricity with lightning and the story of Benjamin Franklin can be given.

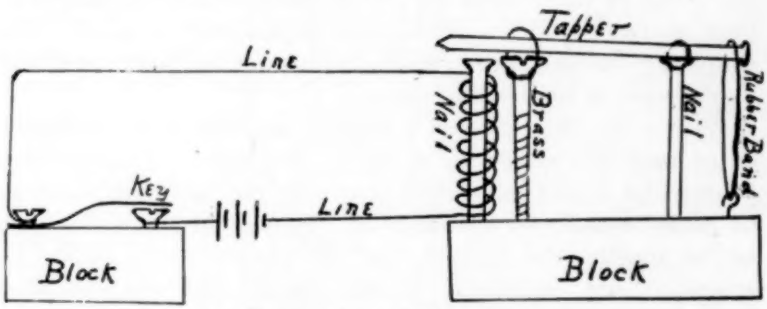
The story of Galvani, professor of anatomy, watching the skinning of frogs' legs, and noticing the twitching whenever the knife came in contact with the clamp, made of another metal, used in holding them, shows the simple step which led to the invention of batteries, with two plates and chemical between.

Volta used plates of silver and zinc separated by cloth wet in salt water when, acting upon Galvani's observation, he invented the "voltaic pile," but pupils can substitute copper plates for silver, and repeat Volta's work successfully. Half a dozen pairs of such plates separated by squares of cloth wet in ammonium chloride solution will ring a bell. The order from bottom to top should be zinc, cloth, copper; zinc, cloth, copper; etc., with wires attached to the bottom and top plates. Repeating a classical experiment of history serves a double purpose.

Since a large part of education consists in the ability to martial facts and to see relationships between them it is very important to make sure that pupils see the various points of similarity between the frogs' legs experiment, the voltaic pile, and the ordinary batteries of today. In each case there are two materials, usually metals, with some moist substance between them. The frogs' legs might have been a piece of beef steak; the current would have been developed just the same. The virtue of frog's legs is that they kick when a current passes through their nerves.

This action of *indicating* a current by some peculiar behavior should be seized upon to lead up to the galvanometer, voltmeter, electric bell, light bulb, etc., as used to test the presence of electricity. Magnetic action as made use of in the galvanometer can be very simply demonstrated by wrapping a compass with a hundred or more turns of magnet wire.

The historic method continues to serve a good purpose as we take up uses which have been made of electricity. A study of the physical difficulties and public indifference which had to be overcome by Morse before the telegraph was a success becomes a lesson in character building as well as in science. Likewise Cyrus W. Field's almost superhuman efforts to lay the Atlantic cable. The gradual development of the electric light from the fragile and inefficient carbon filament which Edison first devised to the tungsten wire in gas filled bulbs is a step in modern progress which has more than doubled the efficiency of our lighting system. Progress in transportation from horse cars to the interurban trolley system is the basis for a thrilling story embracing both elements of civics and science.



An Easily Made Telegraph Set

Unless students are doing metal shop work the making of a motor is beyond them, but a telegraph set may be made very simply and is an accomplishment that will afford considerable satisfaction. It will work successfully if made according to the following directions:

To produce the necessary electro magnet wrap a large nail with about four hundred turns of magnet wire, and drive it into a board a little way. Suspend over it as shown in the diagram another large nail to serve as a tapper.

It will not do for the two nails to touch for the residual magnetism of the iron would hold them together, once in

contact. A brass screw should therefore be set to receive the blows of the tapper. A wire placed loosely around the tapper over the screw serves the double purpose of holding it in place and receiving the return stroke of the tapper—a necessary thing so that dots may be distinguished from dashes. The elastic element needed to give a throw back of the tapper is furnished, as shown in the cut, by a rubber band The sending key is made from a strip of tin or brass which can be pressed down by the finger onto a brass screw as shown.

Every child of early high school age knows something about the four most common applications of electricity in every day life, namely in connection with lighting, heating, communication, and power. That is they are familiar with electric lights, electric heaters, telephones, and motors. The purpose of general science in the schools is to take up subjects of which pupils have some concrete knowledge, and to use this knowledge as a nucleus around which to begin to build the foundations of a scientific education.

Whether all of the four leading uses of electricity mentioned above can be taken up in the course depends upon the length of time available and the demonstration material at hand. The simplest of the four uses to teach, though not the first in practical importance, is the heating effect.

With a few dry cells and a piece of fine wire heat so intense as to melt the conductor is easily developed. Electric light fuses which have been melted in two by too much current may be passed around for examination. Household appliances such as the toaster, the flatiron, and the electric stove should be exhibited and explained. If the burned out element of a flatiron can be obtained and shown it will clear up a great mystery and furnish the occasion to teach the use of insulators.

In the study of the heating effects of a current a knowledge of electric resistance comes as a necessary by product. The reason for the electric toaster, for example, becoming hot while the cord leading to it remains cool should be explained as a matter of difference in resistance, and the kinds of wire offering little or much resistance should be given.

Electric lighting is a topic so closely allied to heating that it is natural to let one follow the other. After making sure that the pupils understand that the source of light from the bulb is the white hot solid filament heated by the current passing through it the path of interest lies along Edison's work and

that of his successors in bulb improvement.

Theoretically the production of light by heating a fiber with electricity is simple, but Edison searched long and far for a *suitable* fiber. All metals then known melted too easily to serve the purpose, so wires would not do—not even platinum. Carbon does not melt and so can be heated to a much higher temperature and therefore give more light than metals.

But carbon is fragile. Edison sought in South America, Africa and other countries for a fiber which when carbonized would be strong enough for the purpose. Finally he made his first successful lamp from a thin strip cut from Bamboo brought from Japan. The strip was bent into the shape of a hairpin and heated until it changed to carbon. On October 21, 1879 Edison turned the current into this first incandescent lamp, and it glowed for forty-five hours before it failed.

Soon better filaments were made of cotton by dissolving it in a chemical which changed it into a pasty mass. This was forced through small holes to make it into fibers, which were then bent into proper form and carbonized by heating.

Carbon filaments were used until a few years ago when a method was found to make wire of a rare element called tungsten. Platinum, which would have been the best metal previously known of which to make filaments, melts at 1750°C, but tungsten stands a temperature of 3400°C, before melting. It will therefore glow with a much whiter and more intense light. Because tungsten can be safely raised to so much higher a temperature than carbon can it gives nearly three times as much light for the same amount of current.

Even a tungsten lamp cannot be raised to anywhere near the melting point for the filament evaporates, blackening the bulb, and soon burns our entirely. To prevent evaporation some bulbs are now filled with gas. Evaporation is much more rapid in a vacuum. In the gas the temperature can be so increased that about twice as much light is given.

A vacuum tube could be heated for a few minutes to the same high temperature that is used in a gas filled bulb, and would give just as much light, but it would not last long. With gas in the bulb the life of the tube is 100 times as long as it would be without gas at the high temperature.

The gas first used (in 1913) was nitrogen, but soon it was found that argon was better, so now a mixture of 80% argon and 20% nitrogen is used.

DEFINITION AND CLASSIFICATION OF GEOMETRIES.[1]

By Professor Ernest P. Lane,

The University of Chicago.

1. *Introduction.* It will perhaps make what we shall have to say easier to follow if we in the beginning outline briefly the plan of this paper. We shall first of all state and explain a very famous and classical definition of geometry. After illustrating this definition by contrasting metric and projective geometry, we shall make some historical remarks to emphasize this contrast, and shall distinguish between synthetic and analytic geometry.

After that, we shall classify some of the better known kinds of geometry, for example, metric, affine, projective, and birational geometries, and analysis situs. Finally, we shall distinguish between algebraic and differential geometry, and shall discuss the distinction between riemannian and non-riemannian geometry, and between euclidean and non-euclidean geometry.

2. *Definition.* The definition of geometry that we shall use is due to the distinguished German mathematician Klein. This definition was announced by Klein in 1872 in his epoch-making *Erlangen Program,* promulgated on the occasion of his entering the philosophical faculty and senate of the University of Erlangen. It can be formulated very concisely in the following words:

Geometry is the study of the invariants of a configuration under a group of transformations.

In order to amplify this definition and make its significance clearer, let us look for a moment at the structure of geometry. In building a geometry the first thing that one does is to select the *space* of the geometry; for instance, a plane, ordinary space, or n-dimensional space. Geometries could be classified according to their spaces. The second thing is to select the *element* in the space. The space is thought of as filled with the elements, which in the most elementary geometry are points, but which may be straight lines, planes, circles, spheres or other things. Geometries could be classified according to their elements. The third thing to do is to build *configurations,* or figures, in the space and out of the elements. Such a configuration in a geometry of the plane made up of points might be, for example, a triangle.

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[1]Read at the meeting of the Central Association of Science and Mathematics Teachers, University of Chicago, Nov. 29, 1929.

The fourth thing is to select the group of *transformation*, or the operations to which configurations are to be subjected. Finally, one studies those properties of the figures which remain unchanged, or *invariant*, when the transformations are carried out. This study is geometry according to Klein.

In order to illustrate our definition, let us consider the distinction between metric and projective geometry. *Metric geometry is the study of the invariants of configurations under the group of motions.* The most familiar elementary geometry is of this sort. The fundamental postulate for metric geometry is the *postulate of superposition*, which in one of the most recent texts is rightly listed as postulate number one and stated thus:

Any geometric figure may be moved without altering its shape or size.

In the statement of this postulate it would have been quite accurate to say "without altering any of its essential properties," shape and size, or angle and distance, being only two of the many metric invariants. A triangle drawn on paper in Chicago and sent by mail to New York still possesses when it arrives in New York all its metric properties.

On the other hand, *projective geometry is the study of the invariants of configurations under the group of protections.* In this geometry a figure may be projected from one place to another without altering any of its essential properties. For example, when the operator of a moving picture machine projects a picture from a film onto the screen before an audience, the two pictures differ in some respects, for instance, in size, but in other respects they are the same picture. It is absurd to suppose that if the picture on the film is "Our Dancing Daughters," the picture on the screen is "The Birth of a Nation." Those properties which the picture on the film has in common with the picture on the screen are unchanged by, or are invariant under, projection, and hence their study is projective geometry.

3. *Historical Remarks.* The contrast between the histories of metric and projective geometry is very striking. Metric geometry is the oldest of all the geometries. Herodotus says that geometry originated in Egypt, and there are two reasons why it may very well have done so. First, the *necessity* existed in the demand for some means of restoring the boundaries of fields after the annual innundations of the Nile. Second, the *opportunity* existed, since the priests constituted a leisure class, who

had time for study. It is said that Thales of Miletus introduced geometry into Greece about 600 B. C. The Greeks organized geometry into a science, or logical system, the best known of the Greek geometers being perhaps Euclid who lived about 300 B. C. The geometry of this time was metric geometry, and among the Egyptians it was not much more than rules for mensuration.

Projective geometry is comparatively modern. It originated in the work of Poncelet, a French officer in Napoleon's army, who started on the disastrous invasion of Russia in 1812. He was wounded at the battle of Krasnoi, left on the field for dead, taken prisoner by the Russians, and put into a military prison at Saratoff. There, in enforced leisure, he began in the spring of 1813 to evolve in his own mind, without the aid of books or paper, a theory of projective geometry. He returned to France in 1814 and in 1822 published the first great book on projective geometry.

Continuing in the historical vein, let us distinguish between synthetic and analytic geometry. The geometry of the ancients was *synthetic* geometry, that is, pure geometry using intuition as a guide and logic as the instrument. It is natural, then, that this should be the kind of geometry to which the student is first introduced in the high school. Contrasted with synthetic geometry, we have *analytic* geometry, which uses coordinate systems, and has the advantage of being able to employ the powerful methods of algebra and analysis to obtain geometric results. However, it should not be forgotten by analytic geometers that every purely geometric theorem must be formulated in a manner entirely independent of the coordinate system used. It is well known that analytic geometry originated with Descartes (1596-1650).

4. *Classification.* We are now ready to classify some of the better known kinds of geometry. For simplicity, we shall confine our attention to the geometry of the plane with the point as element. We shall adopt the analytic point of view, and shall classify the geometries according to their fundamental groups of transformations.

Let us establish an ordinary orthogonal cartesian coordinate system in the plane, so that a general point has coordinates (x, y). Let the same point have coordinates $(\bar{x}, \bar{y})$ after a transformation, referred to the same coordinate system; the coordinate system is supposed not to change during the discussion in this section.

Perhaps the simplest geometry that we can think of in the plane is *translational* geometry, for which the group of transformations consists of the *translations*,

$$(1) \quad x=\bar{x}-h, \qquad y=\bar{y}-k.$$

Another very simple geometry is *rotational* geometry, for which the group of transformations consists of the *rotations* about a fixed point. When this point is the origin, the equations of the rotations are

$$(2) \quad x=\bar{x}\cos\alpha+\bar{y}\sin\alpha, \quad y=-\bar{x}\sin\alpha+\bar{y}\cos\alpha.$$

The result of performing a translation and then a rotation is a *motion*,

$$(3) \quad x=\bar{x}\cos\alpha+\bar{y}\sin\alpha-h, \qquad y=-\bar{x}\sin\alpha+\bar{y}\cos\alpha-k.$$

The motions (3) constitute the fundamental group of transformations for ordinary metric geometry.

Another simple geometry has for its fundamental group the *stretchings*,

$$(4) \quad x=m\,\bar{x}, \qquad y=n\,\bar{y},$$

which may include *reflections*, when one or both of m and n happen to be negative.

A more general geometry than any of these is *affine* geometry, the equations of an affine transformation being of the form,

$$(5) \quad x=a_1\bar{x}+b_1\bar{y}+c_1, \qquad y=a_2\bar{x}+b_2\bar{y}+c_2.$$

Clearly, the affine group includes all the groups previously mentioned in this section. But the affine group is included in the group of *projective transformations*,

$$(6) \quad x=\frac{a_2\bar{x}+b_2\bar{y}+c_2}{a_3\bar{x}+b_3\bar{y}+c_3}, \quad y=\frac{a_2\bar{x}+b_2\bar{y}+c_2}{a_3\bar{x}+b_3\bar{y}+c_3},$$

where

$$\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix} \neq 0.$$

In fact, it can be shown that a projective transformation which makes finite points correspond to finite points and infinitely distant points to infinitely distant points is an affine transformation.

It may be worth while to remark here that, the larger the group is, the fewer the invariants are. Any invariant under a group is obviously invariant under a sub-group. So every pro-

jective invariant is also an affine invariant, but not conversely. Similarly, every projective invariant is also a metric invariant, but not conversely. It follows that all of projective geometry may properly be included in metric geometry. Historically it is true that many projective theorems were discoverd and so included before projective geometry declared its independence and was organized as a separate science.

The group of projections is included in the group of *birational transformations*,

(7) $x = P_1/P_3, \qquad y = P_2/P_3,$

where P_1, P_2, P_3 are polynomials in $\bar{x}$, $\bar{y}$, at most of degree n. There is a very extensive literature of this kind of geometry which it will not be possible to discuss here.

Finally, an even more general transformation than any of those previously considered is the general continuous point transformation,

(8) $x = f(\bar{x}, \bar{y}), \qquad y = g(\bar{x}, \bar{y}),$

where f, g are continuous functions of $\bar{x}$, $\bar{y}$. The study of the invariants under this group is called *analysis situs*. A famous problem of analysis situs is the *four color problem*, to prove that four colors suffice to make a map of the world such that no two adjoining countries are represented in the same color.

5. *Differential Geometry.* From still another point of view geometries can be classified into algebraic, or integral, geometry and differential geometry. Roughly speaking, we may say that algebraic geometry is analytic geometry in which the equations are algebraic. Because of the wide interest in birational geometry, the term *algebraic geometry* has come to be almost synonymous with *birational geometry*. Algebraic geometry considers a configuration as a whole, and hence may be called *integral* geometry. For instance, a problem in this geometry is to find all the intersections of a straight line and a conic; clearly, for the solution of this problem a knowledge of the entire line and conic is required.

Differential geometry, on the other hand, studies a configuration in the neighborhood of one of its elements, for example, a curve in the neighborhood of one of its points. Differential geometry uses limiting processes, and in fact, employs extensively the differential calculus. A problem in this geometry is to define the tangent line at a point of a curve. The well known definition of the tangent as the limit of a secant line through two

points of the curve obviously requires for its statement a knowledge of the curve only in the neighborhood of the point of tangency.

The advent of the Theory of Relativity heralded a renaissance in geometry. Two kinds of differential geometry which have been much in the public mind of late are *riemannian* and *non-riemannian* geometries, each of which is intimately connected with physical theories.

An idea of the nature of riemannian geometry can be easily acquired. In metric differential geometry of ordinary space the element of arc of a curve is given by the well known formula,

$$(9) \quad d\,s^2 = d\,x^2 + d\,y^2 + d\,z^2.$$

The expression on the right is a quadratic differential form, or homogeneous polynomial of the second degree, in the differentials *dx, dy, dz.* Riemann, in his Habilitationschrift (1854) generalized this notion. Let the number of dimensions be n instead of three so that a point has coordinates $x^1, \ldots, x^n$, and let the element of arc of a curve be given by a general quadratic differential form,

$$(10) \quad d\,s^2 = \sum_{i,j}^{1,n} a_{ij}\, d\,x^i\, d\,x^j.$$

Such a geometry is riemannian geometry. One of the problems in this geometry is to determine the lines of shortest length, to take the place of the straight lines of more elementary geometry. These lines of shortest length are called *geodesics*, and are found to be given by the differential equation.

$$(11) \quad \frac{d^2 x^i}{d\,s^2} + \Gamma^i_{jk} \frac{d\,x^j}{d\,s} \frac{d\,x^k}{d\,s} = 0 \quad (i, j, k = 1, \ldots, n),$$

where the summation convention of tensor analysis is observed so that summation with respect to j and k is understood, and where the coefficients Γ^i_{jk} are certain functions of the coefficients a_{ij} and their derivatives, which are called Christoffle symbols, and the formulas for which we shall not write here.

Non-riemannian geometry originated in a paper by Weyl published in 1918. The difference between riemannian and non-riemannian geometry is that in the latter the quadratic form (10) is discarded, and the coefficients Γ^i_{jk} are now any functions of the coordinates $x^1, \ldots, x^n$ that are transformed

in the same way as the Christoffel symbols under the general transformation.

$$(12) \quad x^i = x^i(\bar{x}^1, \ldots, \bar{x}^n), \quad (i=1, \ldots, n), \quad \frac{\partial(x^1, \ldots, x^n)}{\partial(\bar{x}^1, \ldots, \bar{x}^n)} \neq 0$$

6. We shall be able to distinguish between just two more kinds of geometry, namely, euclidean and non-euclidean geometries. *Euclidean* geometry is the ordinary geometry of experience, and is based in part on the famous fifth, or parallel postulate of Euclid which amounts to this:

Through a point one, and only one, line can be drawn parallel to a given line.

Mathematicians tried unsuccessfully for about 2000 years to prove this postulate from the others. Saccheri (1667-1733) almost arrived at *non-euclidean* geometry, but lost his courage and "proved" that two alternative assumptions leading to hyperbolic and elliptic geometry were false. So it remained for Lobachevski, at the University of Kasan in Russia, and for Bolyai in Hungary, to arrive almost simultaneously, about 1825, at *hyperbolic* geometry, in which two, and hence infinitely many, parallels to a given line can be drawn through a given point. Lobachevski published his results first, but Bolyai may have reached his results earlier than Lobachevski. The existence of *elliptic* geometry, in which no parallel to a given line can be drawn through a given point, was implied by Riemann in his doctoral dissertation (1854). Hyperbolic and elliptic geometry together are known as non-euclidean geometry.

7. *Conclusion.* This ends our discussion of the definition and classification of geometries. Such a brief consideration of so large a subject must of necessity have been rather sketchy and in places no doubt actually inadequate. But if we now comprehend any more fully the greatness of our noble science of earth-measurement, and understand any more clearly the relations of its various parts to its whole, then we may agree that the time spent in contemplating these ideas has been not only pleasant but also profitable.

"I have never seen an intelligence test that actually tested intelligence. I make this statement after completing a survey of three of our best known institutions of higher education. We are losing sight of good, old-fashioned common sense."—*Professor Andre Morize, Harvard University.*"

REPORT

OF THE
One Hundred Thirteenth Meeting
OF

Eastern Association of Physics Teachers

HELD AT

JEFFERSON PHYSICAL LABORATORY HARVARD UNIVERSITY

SATURDAY, NOVEMBER 2, 1929

OFFICERS FOR 1929-1930

ROY R. HATCH, President................Mount Hermon School, Mount Hermon, Mass.

FREDERICK M. BOYCE, Vice-President............Phillips Academy, Andover, Mass.

W. W. OBEAR, Secretary....................................The High School, Somerville, Mass.

WILLIAM F. RICE, Treasurer................Jamaica Plain High School, Boston, Mass.

PROGRAM

9:30 Meeting of the Executive Committee.

9:45 Business Meeting.
Reports of Committees.

10:15 Tribute to Prof. Hermann Hahn of Berlin. Prof. N. Henry Black, Harvard University.

10:30 "What is the Nature of Light?" With Experimental Demonstrations. Dr. Franz H. Crawford, Harvard University.

11:30 "Modern Methods of Producing High Vacuum" and Various Phenomena of Electronic Emission in High Vacuum."
With Experimental Demonstrations.
Mr. E. L. Manning, Research Laboratory, General Electric Co., Schenectady, N. Y.

1:00 Lunch at convenient restaurants in Harvard Square.

2:00 Informal Demonstration of New Apparatus by Prof. Black.

2:00 Football Game at Harvard Stadium. Harvard vs. Florida.

BUSINESS MEETING.

President Hatch opened the business meeting with a word of appreciation to Harvard University and Prof. Black for their cooperation in making another meeting possible at the Jefferson Physical Laboratory. He also mentioned the very recent death of Mr. Irving H. Upton upon which suitable action will be taken later.

The following were elected to membership upon recommendation of the Executive Committee:

CHANGING FROM ASSOCIATE TO ACTIVE MEMBERSHIP.

Dudley C. Barrus, Mt. Hermon School, Mt. Hermon, Mass.
John W. Hutchins, 20 Main St. Park, Malden, Mass.
Carl W. Perkins, High School, Fitchburg, Mass.
Augustus Klock, 55 Wendover Road, Yonkers, N. Y.

ELECTED TO ACTIVE MEMBERSHIP.

Wilfred W. Clark, Rogers High School, Newport, R. I.
Spurgeon Gage, Mt. Hermon School, Mt. Hermon, Mass.
Kenneth L. Goding, High School, Amherst, Mass.
Fred Holmes, Memorial High School for Boys, Roxbury, Mass.
John F. Kerrigan, High School, Salem, Mass.
Carroll H. Lowe, High School, Keene, N. H.
Charles F. Taber, Northfield Seminary, Northfield, Vt.
Cyril C. Trubey, High School, Salem, Mass.

ELECTED TO ASSOCIATE MEMBERSHIP.

Francis J. O'Brien, High School, Lawrence, Mass.
Claude C. Farwell, Story High School, Manchester by the Sea, Mass.

REPORT OF COMMITTEE ON MAGAZINE LITERATURE.

JAMES W. DYSON, CHAIRMAN,
Mechanic Arts High School, Boston.

Journal of Chemical Education:
"And Now the Mechanical Color Analyzer." May, 1929.
"The Measurement of Change in Volume on Solution." June, 1929.
"The General Electric Research Laboratory. What it is and what it has accomplished." October, 1929.

"Tycos":
"Defining Aircraft Altitude Records by Means of Temperature and Pressure." April, 1929.
"Aviation and the Weather." April, 1929.
"Apparatus Measures Resistance to Flow of Heat in Homes." April, 1929.

Literary Digest:
"Influence of Sun Spots on Radio." Sept. 7, 1929.
"An Eye That Never Sleeps." Sept. 14, 1929.
"Hail Storms More Destructive Than Tornadoes." Sept. 21, 1929.

Harpers Magazine:
"Building the 200-Inch Telescope." November, 1929.

REPORT OF COMMITTEE ON CURRENT EVENTS.

LOUIS A. WENDELSTEIN, Chairman,
High School, Everett, Mass.

MECHANICS.

On Oct. 21, for the first time in the history of aviation, a seaplane took

off with a load of 169 persons, when the DO-X flew over Lake Constance. The flight lasted nearly an hour.

This achievement marks a new stage of development in aviation and is all the more remarkable in view of the fact that the German and British dirigible airships have never carried more than half the number of passengers taken up on the DO-X, which in addition, carried sufficient fuel to cover a distance of 750 miles. The total weight which the DO-X lifted was 52 long tons, including 17 long tons of useful load, and despite this enormous weight, the seaplane effected a take-off in 50 seconds. It rose quickly to 700 feet, flying westward along the Swiss coast toward Constance and gradually rising to a height of 1200 feet. During its flight, the seaplane developed a speed of 110 miles an hour. With this flight, the DO-X has completed nearly 40 trips and except for a few slight errors, Dr. Dornier's calculations, which more than a year ago were still doubted at a London meeting of aeronautical experts, proved to be correct.

This new seaplane is 230 feet long and 33 feet high, and weighs almost four times as much as any plane previously built.

When the new Italian submarine "Mameli" rose dripping above the water of the Gulf of Spezia, south of Genoa, recently, it brought with it what is said to be a new world's record for an underwater dive. It had sunk to a depth of 383 feet below the surface, nearly forty feet beyond the previous record. The "Mameli" is an 820-ton boat with a length of 212 feet.

The new record is more than two hundred feet lower than the greatest depth at which useful work has been accomplished by a worker in a diving suit. A Spanish diver, Angel Erostarbe, descended to 182 feet in recovering $45,000 in silver bars from the wreck of the steamer "Skyro," sunk off Cape Finistere, Spain. In a special test two officers of the British Navy were lowered to a record depth of 210 feet, where the pressure was ninety pounds to the square inch. They were unable to perform any work, however, since deep-sea divers, even at moderate depths, lose four fifths of their efficiency due to the water pressure and the awkwardness of their heavy suits. At 210 feet they could hardly move.

A new type of speed boat that lifts itself clear out of the water on steel plates shaped like an airplane's wings recently attained a speed of fifty-six miles an hour at its first public test on Long Island Sound near Saugatuck, Conn., using a 220-horsepower engine, only half the power the boat was designed for.

When the queer thirty-foot craft attains full speed its bottom rises until the entire weight of the cigar-shaped hull is supported on four tiny plates or "hydrofoils," with a combined area of only one and a half square feet. Somewhat the same effect is attained in stepped-bottom hydroplanes. The small area of the planes needed in the new speedster is explained by the fact that since water is many times denser than air, a small plane in water has the same lifting effect as the huge wing of an airplane in the air.

A bulbous bow that presses water down instead of to the side, and a stern lifted from the sea by the propellers, helped the "Bremen" to earn the title of the fastest liner. Streamlined throughout, even to the funnels, the "Bremen's" curious shape, bulging in front and tapering behind, is designed to offer the least resistance to water and air. The shape assumed by a falling raindrop is applied to the funnels and, under water, in blisters, one on each side, which give the vessel her pear shaped bow.

Heat.

A revolutionary liquid for cooling airplane motors has been developed by the U. S. Army Air Corps at Wright Field, Dayton, Ohio. As announced by the War Department, it is ethylene glycol, a chemical employed as a base for many antifreeze solutions. Used instead of water in radiators of water-cooled engines, it is said to eliminate more than a hundred pounds of needless weight, increasing a plane's pay load and its speed.

Four and a half gallons of the new fluid replace eighteen gallons of water, a saving of eighty-four pounds. But this also reduces the size of the radiator required and means a further saving of some forty pounds. Also the air resistance of the radiator in flight is diminished, speeding up a plane as much as eleven miles an hour.

Further consequences of its use may be that streamlined radiators may be placed in the wings of a plane, and that oversize water-cooled motors may replace present engines without increase in weight.

The liquid is clear, colorless and odorless, and its constituents may be obtained on the open market at comparatively low expense. It boils at about 400 degrees F., considerably hotter than boiling water.

Several small pieces of ice are more effective in a refrigerator than a large cake of the same total weight, recent tests at the Popular Science Institute of Standards, New York City, indicate. It was found that lower box temperatures can be maintained by using the small pieces.

C. F. Belshaw, a refrigerator specialist of Detroit, Michigan, recently gave the opinion that it is as unsatisfactory to use ice in large cakes in a home icebox as it would be to burn fifty-pound chunks of coal in a furnace.

The kind of gas that puts "Fizz" in your soda water, carbon dioxide, is being used by the Los Angeles, Calif., fire department to "freeze" fires. It is carried under high pressure in cylinders. When released, it shoots out in a cloud of below-zero snowflakes that reduce the temperature and absorb much of the oxygen from the air, thus tending to smother the flames. A special truck has been designed for the department to carry the battery of cylinders that forms this latest unit in the battle of science to reduce the huge annual loss by fire.

Some time ago a test of carbon dioxide gas as a flame extinguisher was made in Germany. Since then, other tests have been conducted in several parts of the United States. The addition of the gas unit to the California fire-fighting equipment is expected to prove valuable in combating chemical, paint, and oil fires, where streams of water are of little use.

Light.

The commemoration of the 50th anniversary of the perfection of the electric lamp by Thomas Edison, was celebrated at Dearborn, Michigan, October 21.

A feature of the celebration was the duplication by Mr. Edison of his final experiment on the incandescent lamp in his original laboratory which was transported from Menlo Park, N. J., to Dearborn by Mr. Ford.

President Hoover said in part: "Our scientists and inventors are among our most priceless national possessions. There is no sum that the world could not afford to pay these men who have that originality of mind, that devotion and industry to carry scientific thought forward in steps and strides until it spreads to the comfort of every home."

At the ceremonies attending the celebration, the Edison Institute of Technology, the gift of Mr. Henry Ford, was dedicated.

Among those on the long list of notables present at the dinner was Madame Curie, co-discoverer of radium.

Greetings from Berlin were brought to the dinner guests in a brief talk by Prof. Albert Einstein over the trans-atlantic radio telephone.

Using the principle of a nursery toy, the familiar rotating, varicolored disks that blend into a single shade, Dr. John H. MacGillivray, of Purdue University, Indiana, has devised an apparatus to aid farmers in determining the ripeness and quality of tomatoes from their color. By altering the ratio of the exposed areas of the different colored disks, he is able to produce all shades in which tomatoes appear; and by comparison, to classify the fruit accurately as to ripeness.

The disk, spun by a small electric motor, is placed beside the fruit, and the colors altered until the exact matching shade is discovered. Fully ripe tomatoes have been found to have practically the same color, no matter from what section of the country they come. With the MacGillivray device it is hoped to establish a standard that will result in better grades of canned and fresh tomatoes being sold for public consumption.

Sound.

Sound waves too high-pitched to be heard by the human ear now analyze liquids in a new method of startling precision announced by Dr. J. C. Hubbard, Johns Hopkins University physicist. By passing them through a vessel filled with an unknown fluid, a chemist can tell what the liquid is, what kinds of chemicals it contains, how much of each, and whether the liquid is adulterated with any impurity.

The new process was developed in the laboratory of Alfred Loomis, New York banker and experimenter of Tuxedo Park, N. Y. Dr. Hubbard found that no two substances transmit sound waves at the same speed; that the speed is, in fact, a characteristic property of each individual substance; and that it can be measured precisely. The result is a new method of analysis that may supplant hours of work in a chemical laboratory.

So successful have proved experiments in two-way radio-phone communication between pilots of speeding mail planes and ground stations that the system is now to become a regular service on the 200-mile western leg of the transcontinental route between Chicago and San Francisco. Twelve ground stations in seven states will keep in touch with pilots at all times, and advise them on weather conditions ahead. A somewhat similar system has been in use in the East for some time, but the pilots have been able only to listen to instructions and not to reply.

The revolutionary innovation will enable a pilot to talk with ground officials even if he is 12,000 feet above sea level and lost in the clouds.

The twelve ground stations already built or authorized are at Oakland and Sacramento, Calif.; Reno and Elko, Nev.; Salt Lake City, Utah; Rock Springs and Cheyenne, Wyo.; North Platte and Omaha, Neb.; Des Moines and Iowa City, Iowa; and Chicago. Thirty-five planes flying over this route will carry the radiophone equipment.

Electricity.

Static, the bane of radio fans, is being put on the credit side of the ledger by the U. S. Navy Bureau of Aeronautics. The crashes of inter-

ference that often ruin broadcast reception are used by weather observers to locate the direction of storms and so aid flyers on the airway between Anacostia, D. C., and Lakehurst, N. J., the home of Navy lighter-than-air craft.

A pair of six-foot loop aerials, at right angles to each other, record the static in the Navy observation room, in Washington, D. C. When a loop aerial is edgewise to the source of static the volume is greatest. So the aerials are swung about until the direction of maximum static is determined. From that direction storms may be expected, as static is thought to be caused by electrical disturbances closely related to the approach of storms.

Radium, priceless tool of medicine, has a new use. In a rubber factory at Leningrad, in Russia, it prevents fires.

Its remarkable fire-protecting quality is due to the ability of radium to make the air around it a better conductor of electricity. Hitherto sparks of static electricity that jump from rubber fabric passing over the factory rollers have constituted a dangerous fire hazard, since a rubber drying room is filled with inflammable vapors. Now the presence of a small capsule of radium permits electricity to leak slowly and harmlessly from the rollers into the air, instead of accumulating a sufficient charge to produce a fat spark.

Since only one milligram of radium is used the novel method is said to cost only a few dollars. The radium need not be renewed, since it lasts for centuries.

A more "popular" presentation of Prof. Albert Einstein's new field theory uniting laws of gravity and electricity has recently been submitted to the Prussian Academy of Science by that distinguished physicist himself.

Though the revised text is by no means easy reading, it is said to be a little more comprehensible to most scientists than the six-page leaflet which recently announced Einstein's latest discoveries.

The original text abandoned classical mathematics and set forth Einstein's sensational conclusions about the behavior of objects, time, and space in a system of geometry largely devised by Einstein himself. In the present work, entitled "The Uniform Field Theory and the Hamiltonian Principle," the Berlin physicist has expressed his conclusions by the more familiar mathematical methods developed by the English mathematician, William Hamilton.

REPORT OF COMMITTEE ON NEW BOOKS.

J. Herbert Ward, Chairman,

Classical High School, Providence, R. I.

The Nature of the Physical World, by A. S. Eddington. Macmillan Company. One of the very best books printed on any subject last year. No teacher of Physics should be without it. Either it should be on the library list at school or on his desk at home.

The writer started to keep notes and references which he could use in some way in connection with his classes. He now has 22 sheets of thesis paper in outline form as a result of reading the 353 pages of this revolutionary work.

The Einstein theory is analyzed, illustrated and made as clear as possible to us relatively feeble-minded beings. Listen to some conclusions:—Thermodynamical equilibrium equals fortuitous concourse of atoms."

"Space and Time are finite but unbounded." "Every body continues in its state of rest or uniform motion in a straight line except in so far as it doesn't." "Motion does not tire anybody." "The earth goes anyhow it likes." "At the present time our race is supreme, but is probably not the only one endowed with consciousness." The Quantum Theory is very carefully presented in all its forms and is accepted as a corollary of Einstein's proposition. Again we have some thought-provoking ideas: —"In a model atom the electrons traverse their orbits under laws of electrodynamics, but they jump from one orbit to another in a way inconsistent with these laws." "A particle may have position or it may have velocity but it cannot in any exact sense have both." "The laws of conservation of energy and momentum are mathematical identities." "Physics is no longer pledged to a scheme of deterministic law." "Velocity does not exist in the present time but in the future perfect."

Finally, the author journeys into the metaphysical realm of thought. "Volition is genuine." "Now no clear distinction between the natural and supernatural." "Strict causality is abandoned in material world." "Human nature either of itself or as inspired by a power beyond is capable of making legitimate judgments of significance."

The above is offered with the hope that some suggestion of the nature of the work may have been given.

Direct Current Electricity, by L. Raymond Smith, McGraw-Hill Book Co., New York. This is a small book of 250 pages. The book is arranged in chapters containing one subject. Each topic is developed by means of diagrams and at the end of the chapter there are illustrative problems. The purpose of the text: (1) to enable the layman to grasp the fundamental principles of the electric current and the application of these principles to his daily life; (2) to enable the student who expects to follow electricity as a vocation to get a thorough preliminary training in the subject, that later he may proceed more rapidly to advanced study. This is a first-class drill-book for Technical High Schools or for technical courses in electricity. Chapter II on series and parallel circuits is unusually good on this familiar subject. Chapter XIV on D. C. generators is worth the price of the book.

TRIBUTE TO PROF. HERMANN HAHN OF BERLIN.

By Prof. N. Henry Black,
Harvard University.

It is appropriate that the Eastern Association of Physics Teachers devote a little time to a review of the life and attainments of a former foreign member of this organization. Professor Hermann Hahn of Berlin was a veteran physics teacher, a trainer of physics teachers, and for many years a leader in the movement to introduce into the higher schools of Germany laboratory experiments.

Hermann Hahn was born in Wiesbaden on April 25, 1857 and died in Berlin on April 19 of this year. He was graduated from the Realgymnasium in his native city, took his doctor's degree in mathematics and science at the University of Berlin, and after one year of practice training in 1886 began teaching in the Margareten-Schule. His outstanding attainments immediately attracted attention and in 1900 he was appointed to the Dorotheen städlisches Realgymnasium, also in Berlin. Here he came under the influence of the great physics teacher Schwalbe, whose pioneer work Hahn carried on and developed far beyond anything that Schwalbe had attempted. From 1900 to 1905 he gave courses for the

Physics Teachers in Berlin cn the methods of conducting laboratory experiments. For many years he lectured at the Urania, an organization for popularizing science; also, in the summers he gave vacation courses on laboratory experiments in physics. In 1906 he was promoted to the rank of Professor and seven years later became the director of a professional shool for the science teachers in the higher schools of Berlin. In 1914 he was signally honored by being appointed first director of the just established Prussian Bureau for Science Teaching.

Hermann Hahn's astounding capacity for work is revealed in the fact that these posts were filled while he was carrying on at the same time his teaching in the Dorotheen städlisches Realgymnasium and while he was publishing a constant stream of articles in periodicals and writing his two monumental works. As Associate Editor of the *Zeitschrift für den Physikalischen und Chemischen Unterricht* from 1902 to the time of this death, he did careful and conscientious work in selecting matter for publication and himself contributed constantly. His Encyclopedia of so-called *Physikalische Freihandversuche*[1] in three volumes was incomplete at the time of his death, but with characteristic foresight he had selected a successor to finish it. His last work was the third edition of the *Handbuch für Physikalische Schülerübungen.*[2] This is a scholarly compilation of the best experiments for laboratory instruction which are available in German, French, English, and American textbooks, rewritten and adapted with copious historical notes and critical comments. In general, the style of Hahn's writings bears the earmarks of the historian, for in his university course he included training in historical methods and always went back to origins in discussing debatable questions.

Many honors in many lands came to Hermann Hahn in the course of his long and fruitful life. In March, 1918, he was made Geheimer Regierungsrat. Twice at the request of the Prussian Minister of Education the date of his retirement was postponed, and when he did finally retire in 1924 he was asked to name his successor. It was in 1909 that he became foreign correspondent for the Eastern Association of Physics Teachers. Two years later the Swiss government asked him to give some lectures on *Teaching Physics by Doing* at their first vacation school for Middle-School teachers in Zürich. In 1913 he was made an honorary member of the Moskow Association for the Advancement of the Physical Sciences. His exhibition of school apparatus received an Honorary Diploma at the World's Fair in Brussels. The year of his retirement from active teaching brought him the further recognition of honorary membership in the Berlin Association for the Advancement of Science Teaching.

His professional significance lies first in the pioneer work that he did in promoting student quantitative laboratory experiments; second, in his training of physics teachers; third, in his creation of a fairly ideal layout of rooms for the teaching of physics; fourth, in his organization of the Prussian Bureau for Science Instruction, which is an indispensable source of advice and guidance to matters pertaining to science teaching; and lastly, in the extension courses which he gave to prospective teachers of physics.

A tremendous worker, genial friend and well-read companion, a persistent drillmaster but a scholar with that perfect combination of keen mind and excellent judgment—Hermann Hahn—we shall not soon find his equal.[3]

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[1] Published by Otto Salle, Berlin W., in 1912.
[2] Published by Julius Springer, Berlin, in 1929.
[3] Prof. Black gave several personal reminiscences of Prof. Hahn and showed slides picturing Prof. Hahn and his school.

THE NATURE OF LIGHT.

Dr. Franz H. Crawford,
Harvard University.

I wish to review briefly some of the experimental evidence which has to do with the nature of light. At best no single experiment is able to settle such a question definitely and it is only by gathering together a great number of experiments of varied sorts that any idea as to the general nature of any phenomenon can be obtained. At the present time the question whether light is more essentially a wave motion or a stream of high speed corpuscles can best be considered by looking at some of the experiments which have in the past given evidence one way or another.

What are some of the chief properties of wave motion? In the first place, any wave motion in a homogeneous medium is characterized by a perfectly definite velocity; thus waves traveling in a piece of phosphor-bronze wire under tension, waves in a spring, or air waves can be shown to have a perfectly definite rate of propagation, depending upon the density of the medium and its elasticity. Now we are all aware of the fact that the possession of a very definite velocity, namely 3×10^{10} cm. per second, on the part of light is very characteristic. All attempts to vary this velocity by changing the nature or state of motion of the source led to no results. This consequently suggests that light may be a wave motion, and if so, that there must be some elastic medium in which the motion is taking place. It was to fulfill this supposed necessity that the ether was invented, and endowed with extremely small density, practically negligible viscosity, and rigidity, which startlingly enough came out to be greater than that of steel. A medium with any less striking properties than this could not give the required velocity for light waves. On the other hand, if it is hard to see why a stream of bullets or corpuscles should possess an unalterable velocity; one would naturally suppose that their velocity might depend in some way upon the temperature and nature of the source.

A second characteristic property of wave motion in general is the ability to get around corners. You have doubtless heard a band around the corner of a building and noticed the low notes reaching you before the high ones; or have seen ocean waves bending around an obstacle such as a small island or large rock.

Again with this apparatus for projecting water ripples we can show the bending of these surface waves of short length around the edge of an obstacle. Now it is found that light does precisely the same sort of thing and does not travel in straight lines when we examine in *detail* its motion around relatively small obstacles. But before considering this further suppose we recall the method of explaining the propagation of waves which Christian Huyghens first proposed. As you know, he conceived of a wave as being made up of the resultant of tiny spherical wavelets diverging from points on a previous wave front. It is the mutual destruction of the tiny wavelets at all points but those on the wave front which gives the appearance of a plane wave traveling steadily forward. It is possible to show that this state of affairs actually exists by placing an obstacle in front of a wave having a very small hole punctured in it so as to allow one of the tiny Huyghens wavelets to pass through. The result is, since we have no other wavelets to interfere, that there is this feeble spherical wave spreading out from the opening as away from the course. We see at once that if two such openings are made in the obstacle it is possible for these two elementary wavelets to reinforce at certain points and cause a greater motion of the vibrating medium or to interfere, producing perhaps no motion at all.

This possibility of interference we can illustrate very readily in the case of water wavelets. In the case of light waves it can be shown by shining light on a soap bubble film or on a water surface on which a small amount of oil has been poured. The waves reflected from the upper and lower surfaces respectively of the film are one or more wave lengths out of step and consequently it is possible to observe interference. We may also repeat the experiment of the water ripples passing through two small openings by a precisely similar arrangement in the case of light and we find again interference, though the resulting patterns are more complicated than those revealed by the relatively crude method of investigation which we used in the case of water waves. The exact patterns, however, can be computed very precisely from the widths of the openings and their distances apart and the wave length or lengths of the light employed. Very interesting interference and diffraction patterns can be observed by allowing a light to pass through a very small slit or opening or to pass through a needle point, around a fine screw thread or other small obstacle. A photographic plate placed

some distance beyond the obstacle gives an image which bears very little resemblance to the obstacle itself, thus showing that the shadow is by no means geometric. It is for this reason that the images from microscopes under very high magnifications must be interpreted with a considerable amount of caution.

Recent experiments by Professor Lyman in this laboratory on the diffraction patterns formed by monochromatic light from a very narrow slit passing through a rectangle constructed of razor blades have shown that the predictions of the wave theory are verified within a very small fraction of a per cent.

The behavior of a water wave passing through a number of small, closely spaced openings can be paralleled in the case of light by a diffraction grating. Here instead of having a few openings as many as 10,000 very narrow slits or scratches are arranged side by side. A parallel beam of light passing through this grating is broken up into a central band of white light and side bands of various orders. From the position of a given color in one of the side bands its wave length can be evaluated very precisely and this perhaps serves as the most accurate absolute instrument for wave length determinations.

These general properties of constant velocity of propagation, of ability to bend around obstacles, and of ability to interfere all seem to require wave motion for their explanation. On the other hand, since about 1900 a very large number of experiments have been collected whose explanation is not so simple; in fact, they suggest at once that light may not indeed be a wave motion but consist of a stream of extremely small corpuscles or *quanta* of energy each of an energy value determined by the particular color of the light being examined. The necessity for some such picture can be realized by considering in one's mind the following situation: Suppose a number of battleships in a small harbor with waves rolling in from the ocean into the harbor. We should expect in general (1) that the ships would gradually begin to oscillate up and down in time with the waves; (2) that all of the ships would be affected; (3) that the effect on any given ship would vary as the height of the oncoming waves increased. Similarly, if we should picture the arrival of a set of plane waves on a group of atoms we might imagine that a similar happening should take place; in case the electrons in the atoms were violently enough shaken we might conceive of an electron as being thrown entirely out of the atom. There would be no reason to suppose, however, that one atom would be more likely to lose

electrons than any other. When, however, this experiment is carried out with either light falling on a solid such as zinc or one of the alkali metals, or X-rays passing through a gas such as mercury or air, an entirely different sort of happening takes place. In the first place, the ejection of electrons begins within, say, a ten-millionth of a second after the light waves or X-rays are turned on. Apparently no time is required for the oscillating motion to build up. In the second place, only an occasional, perhaps every 10,000th or every 100,000th atom is affected at all. The others remain quite as before. And finally, the violence with which electrons are thrown out into the gas or solid is completely independent of the intensity of the original light. Increasing the density of the light merely increases the *number* of electrons without changing the velocity which they possess when they emerge from the atom. The most natural explanation of such behavior is, of course, to assume that the atoms of the gas were not being acted on by a uniform homogeneous wave or series of waves but by a stream of bullets or corpuscles. When an atom absorbs one of these corpuscles it may absorb so much energy as to be able to eject an electron. If the atom is not hit by one of the corpuscles it is completely unaffected. Since only a relatively small amount of the space occupied by the gas is actually filled with atoms we might expect only a relatively small number of atoms to be affected at all. Furthermore, as soon as the light is turned on some atom has a possibility of being hit, and we should not have to wait for any resonance effect as in the case of the battleships being acted on by the incoming water waves.

These results can be very clearly shown by allowing X-rays to pass through a gas which is saturated with water vapor. Under these circumstances the electrons which are ejected by the absorbed quanta of X-rays sail off through the surrounding atoms, ionizing them as they go. It is well known that if the gas is dust-free and slightly supersaturated, the mixture tends to condense on the ionized particles. Consequently, if the gas chamber is illuminated with a brilliant light it is possible to photograph the paths of the ejected electrons. We see in such photographs as those made by C. T. R. Wilson in Cambridge that in the width of the beam across a given gas chamber let us say only two or three dozen atoms had electrons ejected; the other millions of atoms were entirely unaffected, a behavior which is entirely inconsistent with the wave picture of light.

We therefore find ourselves confronted with the necessity of saying that light in its grosser aspects behaves essentially as we might expect a wave motion to behave; that is, as long as the obstacles placed in its path are rather large or of the same order of magnitude as its wave length. When, on the other hand, the obstacles are relatively small compared with the wave length of light (as obtained by a diffraction grating, say) we can no longer treat the approaching wave as completely uniform; we must regard it rather as having more or less speckled appearance, the energy being concentrated in certain parts, producing the effect of a continuous wave in certain cases and the effect of a stream of corpuscles in others. On this basis it is possible to account for the diffraction and interference patterns observed from the experiments to which I referred earlier by saying that the wave theory gives proper results not because light is really a wave motion but from the fact that it gives on the average, of a certain number of light quanta passing through a given slit, the relative number which will arrive at various parts of the image in a second. Thus if the wave theory predicts that a given part of the pattern shall be very intense, that merely means that a large number of quanta will arrive there in a given time, whereas a small number will arrive at the point where the wave theory predicts darkness or relative darkness. No theory, however, has been brought forward which is capable of saying to what point in the interference pattern a given quantum will go. It is merely a question of probability and of a certain number a given fraction will ultimately arrive at a given point but we have no way of saying which quanta of that given number will go this particular point. We thus see that the first approximations to the true nature of light gave the average behavior and it is usually simpler to discover an average behavior than a fine structure behavior. It is important to remember that because light may in the ultimate analysis consist of these small discrete bundles of energy does not detract from the usefulness of the wave theory, since this accounts quantitatively for most of the major effects observed in ordinary experiments on light, and it is only in the case of very special experiments involving objects minute compared to the wave length of light that we are particularly troubled by a departure from a wave-like nature.

Note: Prof. Crawford illustrated parts of his paper by experiments showing wave systems and by slides showing the interference of light waves after passing through very small openings.

MODERN METHODS OF PRODUCING HIGH VACUUM AND VARIOUS PHENOMENA OF ELECTRONIC EMISSION IN HIGH VACUUM.

MR. E. L. MANNING,

Research Laboratory, General Electric Co., Schenectady, N. Y.

Somewhat less than three hundred years ago, the distinguished pupil of an equally distinguished investigator showed the world that "Nature abhors a vacuum" to a limited extent only. We have, then, became accustomed to the fact that the atmosphere, at standard conditions, exerts a pressure equivalent, or nearly equivalent, to that of a mercury column 750 mm in height. Today, the word "vacuum" is applied, widely, to so many different things, from gasoline systems through household cleaners and liquid containers to radio tubes, that it would be strange not to find many and widely different opinions concerning what a vacuum really is. I'm not going to tell what a vacuum is, but I would like to state, most emphatically, what it is NOT. There seems to be a common impression that a vacuum is empty space—an impression persisting in spite of Dr. Whitney's famous address, "The Vacuum—There's Something in It."

Without blushing, we nowadays refer to the number of molecules of gas per unit volume, and know that whatever complications they may involve, individually, they are separate and accurately numbered. When they change their number from any cause, when some break down and others combine,—we also know and count the effects. Without attempting to give exact figures, we know that there are nearly 30 billion-billion molecules per cubic centimeter of air under ordinary conditions, and that when the first practical incandescent lamps were evacuated, they still contained over a million-million molecules of air. It will be understood, then, that an evacuated bulb contains a good deal more than empty space.

So many methods of removing gas from an enclosed vessel have been, and are being used, that it would require much more time than my present allowance to describe, even briefly, all of them. I have listed the principal methods for producing low pressures; I shall speak of but three of those listed, and then as briefly as clarity will permit:

I. Mechanical Pumps:

1. Piston Pumps.
2. Toepler and Sprengel mercury pumps.
3. Rotary mercury pumps.

4. Rotary oil pumps.
5. Gaede "Molecular" pump.

II. Mercury Vapor Pumps:

1. Gaede "diffusion" pump.
2. Langmuir condensation pump.

III. Physical Chemical Methods:

1. Charcoal or other absorbing agent at low temperatures.
2. Cleanup of residual gases by chemical reactions.
3. Cleanup of gases by ionization methods.

Discussion will be confined here to the molecular and condensation pumps. Since it is necessary to do more than remove gas from the actual space being evacuated, some mention will be made, necessarily, of the process of outgasing electrode structures by high-frequency heating, and the problem of high-voltage cleanup, which may be more or less permanent, will be touched.

In many modern vacuum systems, the high vacuum pump does not exhaust into the atmosphere, but into a so-called "rough" vacuum (pressure much lower than atmospheric) obtained by means of another pump in series with the high vacuum pump. In general, the higher the degree of vacuum desired, the smaller the exhaust pressure should be. The degree of vacuum obtainable,—that is, the lower limit of pressure that may be attained in a closed vessel connected to the pump,—depends to a large extent on the exhaust pressure used.

In the case of the mercury vapor pumps, there is theoretically no lower limit to the pressure which may be attained, while in that of the Gaede molecular pump the limiting pressure bears a constant ratio to the exhaust pressure. A little thought will show that with a given pump the rate of exhaust will vary inversely with the volume of the vessel to be exhausted. The speed of exhaust, for a given vessel, will gradually decrease as the exhaust proceeds, so that as the pressure in the vessel approaches the limiting pressure, the rate of exhaust decreases rapidly until it becomes zero when the final possible low pressure has been reached.

The actual speed of exhaust depends not only upon the design of the pump but also upon the diameter and length of the connecting tubing between pump and vessel to be exhausted. The pump and tubing together really constitute a system which is the equivalent of a pump of lower speed than that of the pump alone. Thus it follows logically that in operating vacuum pumps of high speed it is essential to use tubing of large diameter and short

length between the pump and the vessel to be exhausted if full advantage is to be taken of the speed of the pump. The speed of a pump may be looked upon as the reciprocal of the resistance to the flow of gases through it; hence it can easily be seen how seriously the speed of a high vacuum pump may be limited by the resistance of the tubing unless this is of very large size. It also follows from this same argument that in the case of a low speed pump such as the Gaede diffusion pump (speed approximately 80 cm^3/sec.) or a rotary oil pump (speed approximately 100 cm^3/sec.), the resistance of the tubing, as long as it is not too large, is not nearly as important a factor as in the case of high speed pumps.

The Gaede molecular pump marked a distinct advance in the design of pumps for the production of high vacua. All previous high vacuum pumps used an exhaust arrangement which followed the original idea of von Guericke, separating a definite volume of gas from the vessel to be exhausted, and giving it up to a fore-vacuum or to the atmosphere. It is absolutely essential in such pumps to separate, as much as possible, the rough side from the higher vacuum side. This may be accomplished in mechanical pumps by tight-fitting pistons and valves, and in the mercury and oil pumps by means of the liquids themselves. On the other hand, in the molecular pump there is no separation, either piston or fluid, between the high vacuum and the fore vacuum. The gas is dragged along from the vessel to be exhausted into the fore vacuum by means of a cylinder rotating with high velocity inside a hermetically sealed casing. Now, at ordinary pressures, the viscosity of the gas is independent of the pressure, hence the difference in pressure between intake and exhaust openings depends only on such factors as speed of rotation of the cylinder, coefficient of viscosity of the gas, length of slot in the case, and so on. At low pressures, however, the number of collisions between gas molecules becomes relatively small as compared with the number of collisions between the gas molecules and the walls. Under these conditions the molecules tend to take up the same direction of motion as the surface against which they strike, if the latter is in motion. This makes the pressure ratio constant and independent of the pressure in the fore-vacuum. The speed of the pump varies with the magnitude of the rough-pump pressure, and shows a maximum speed of about 1400 cm^3/sec. with a rough vacuum of 0.01 mm. For comparison, the slide also shows the curve for a Gaede rotary

mercury pump, with a speed of about 130 cm^3/sec. at the maximum.

The fact that a reduction in pressure can be obtained by a blast of steam or air has been known and applied in industry for a long time. In steam aspirators or ejectors such as those used for producing the low pressure required in the condenser of a steam turbine, the high velocity of the jet of steam causes a lowering of pressure, so that the air to be exhausted is sucked directly into the jet. Gaede and Langmuir have each devised pumps operating on this principle. A blast of mercury vapor carries along the gas to be exhausted into the condenser. In order to introduce gas into the mercury blast, Gaede has used diffusion through a narrow opening, while Langmuir has made use of the fact that the mercury atoms, colliding with the gas molecules, must impart to the latter a portion of the momentum which the mercury atoms possess because of their high average kinetic energy. The mercury atoms themselves are removed rapidly from the stream of mixed gases by condensation on the cooled walls.

A great advantage possessed by Gaede's diffusion pump over previous types of pumps lies in the fact that theoretically there is no limit to the degree of vacuum which can be attained by its operation. This pump, however, has the double disadvantage of low exhaust speed, and the necessity of carefully regulating the temperature of the mercury vapor. Since both these disadvantages are removed in the Langmuir mercury vapor pump, the while retaining the advantage of the diffusion pump, we will discuss only the condensation pump.

The pump, which may be of glass or of metal, contains a bulb or boiler holding the mercury. This is heated, either by gas or by electricity, so that the mercury evaporates at a moderate rate. The mercury vapor flows through a nozzle, carrying with it gas molecules which reach the neighborhood by diffusion from the vessel to be evacuated. The mercury atoms are prevented from diffusing back in the wrong direction by cooling the walls of the tube near the mercury vapor outlet. The success of the pump rests on the fact that the mercury vapor is rapidly condensed as it leaves the jet, and the subsequent temperatures encountered are so low that the mercury does not re-evaporate to any measurable extent. Hence the name "condensation" to designate pumps based on this principle. In order that such pumps may function properly, the outlet of the cooling chamber surrounding

the nozzle must be placed at a somewhat higher level than the lower end of the nozzle. The other dimensions of the pump are relatively unimportant, save that the distance between the nozzle and reservoir for the condensed mercury must be sufficiently great so that no perceptible quantity of gas can diffuse back against the mercury vapor, and that a large enough condensing area is furnished.

The pump may be made in any suitable size. Some have been constructed in which the tube and the nozzle were one and a quarter inches in diameter, while in other pumps this tube was only one quarter of an inch in diameter and the length of the whole pump was only about four inches. It is true that the larger the pump the greater is the speed of exhaustion that may be obtained.

Unlike Gaede's diffusion pump, there is nothing critical about the adjustment of the temperature of the mercury boiler. With an electrically heated pump having a nozzle seven-eighths inch diameter a certain pump began to operate satisfactorily when 220 watts of energy were supplied to the heating unit. The speed of exhaustion remained practically unchanged when the heating current was increased to the point where some 550 watts were supplied.

The back pressure against which the pump will operate depends, however, upon the amount and velocity of the mercury vapor escaping from the nozzle. In the case mentioned, with 220 watts input, the pump would not operate with a back pressure exceeding 38 microns, while with 550 watts input, back pressures as high as 600 microns did not affect the operation of the pump.

Observations taken with the ionization gauge, at the laboratory in Schenectady and elsewhere, have shown that it is possible with the Langmuir condensation pump to obtain pressures which are of the order of one thousandth micron or less. There is no lower limit (other than zero) below which the pressure cannot be reduced, theoretically. In practice, the limiting factor which ordinarily makes it possible to obtain pressures lower than one thousandth micron, is the continuous liberation of gas from the glass walls or the metal parts. Thus the vacuum actually attained depends partly on the type of pump used, and partly on the rate at which gases are given off from the walls of the vessel being exhausted and from the metal parts inside that vessel.

The gases occluded on the walls of glass vessels consist for the most part of water vapor and carbon dioxide gas, along with

slight amounts of carbon monoxide and other gases which are not condensible at the temperature of liquid air. Metal parts usually contain carbon monoxide and hydrogen gases. In order to eliminate these gases it is essential to heat the glass walls and metal parts to as high a temperature as practicable. The longer the duration of such heating and the higher the temperature used, the lower the pressure of the gases remaining at the end of the exhaust process.

A usual procedure is to heat the glass vessels in an oven, during exhaust, for an hour or longer, using temperatures that run from 300 to 400 degrees C, depending on the kind of glass used. Where a very high degree of vacuum is desirable it is possible to heat the glass to temperatures higher than those mentioned, by reducing the air pressure in the oven itself so that the glass walls of the vessel will not collapse because of external pressure on the softened glass.

In the case of metal parts the elimination of gases is a more difficult matter. Where these parts are so constructed that current can be passed through them, they should be heated to as high a temperature as the metal will stand without injury. Sometimes metal structures, such as the plates (anodes) of vacuum devices, can be heated to incandescent temperatures by the bombardment of electrons thrown from the emitting electrode. The heating of metal parts by eddy current loss,—that is, surrounding these parts with a coil carrying high frequency current —is a practice that has materially aided the rapid, and hence the economical exhaust of most of the smaller vacuum tubes on the market today. Briefly described, the high frequency furnace so used is nothing more than a small broadcasting station, with a coil concentrating the output energy instead of the usual antennae. Heating the metal parts in a vacuum furnace before putting them in the glass vessel also assists materially in the subsequent exhaust on the pump. Special care is always taken to remove all traces of grease and oil from machine-made parts, by washing in acetone and alcohol and drying thoroughly before assembling in the glass vessel.

In order to eliminate mercury vapor and condensible gases emitted from the grease used on the ground glass joints between pump and vessel to be exhausted, it is necessary to use some form of refrigerating chamber in which these vapors are condensed. Without going into detail, I may say that liquid air is perhaps the most efficient and widely used agent of this sort.

I suppose it is not quite accurate to say that, once a good vacuum has been obtained, it is almost as difficult to measure the pressure attained as it is to produce the low pressure. I am going to conclude this discussion of high vacua with a brief mention of two or three of the usual methods of measuring low pressures.

For many purposes the McLeod gauge is quite satisfactory. Actually, this gauge is simply a barometer, so arranged with an ingenious amplifying system that small changes in height can be read accurately. The gauge represents an interesting application of Boyle's law to very low pressures. By compressing to a very small known volume, a given volume of the gas whose pressure is to be measured, the pressure is amplified several thousand fold and may be read directly.

It is evident that the McLeod gauge does not indicate the pressure of mercury vapor. Neither will it indicate the pressure of condensible vapors such as those of oil, water, and ammonia. Even in the case of carbon dioxide the gauge is very inaccurate. If it is used to measure very low pressures, such as those produced by Gaede molecular or Langmuir condensation pumps, a liquid air trap should be inserted between the gauge and the remainder of the system in order to prevent diffusion of mercury vapor into the vessel to be exhausted.

If the bulb and tubing of a McLeod gauge are carefully dried, to eliminate the presence of a film of water, the gauge is quite reliable, measuring air or the so-called permanent gases, down to pressures of 0.01 mm. of mercury, and is probably just as exact at still lower pressures.

The second type of gauge frequently used in high vacuum work is the resistance gauge, often called a Pirani-Hale gauge. At ordinary temperatures the heat conductivity of gases is independent of the pressure. As the pressure is decreased, however, a point is reached at which the heat conductivity begins to decrease with decreased pressure. At very low pressures the coefficient of heat conductivity of gases varies with the pressure. An ordinary incandescent lamp might serve as such a iresstance gauge, although better results would be obtained by certain refinements, such as keeping constant the heat loss through the filament supports. A Wheatstone bridge arrangement is often used for measuring the resistance changes, and in order to increase the sensitivity of the arrangement, an exact duplicate of the gauge is often exhausted as carefully as possible

to an extremely low pressure, sealed off, and inserted in one arm of the bridge as a compensator. Such a gauge, properly constructed and used, may have a sensitivity of 0.00001 mm., or less.

An electron stream passing through a gas will ionize the latter when the velocity of the electrons exceeds a certain value. In the process, an electron is knocked out of a neutral atom, leaving the residual portion of the atom positively charged. The amount of ionization produced by a given electron current increases with the pressure of the gas. This fact has been used qualitatively for the detection of low gas pressures. Almost any three-electrode tube may be used as an ionization gauge; in fact, during test and later during inspection of pliotrons made commercially, so-called "gas" readings are taken, which cause the tube itself to serve, practically speaking, as its own ionization gauge. Essentially, any such gauge consists of a source of electrons (filament, cathode), a collector of electrons (anode, plate), and a collector of positive ions. This ion collector is often placed between cathode and anode, and is connected through a galvanometer to the negative terminal of a battery whose positive terminal is connected to the most negative end of the cathode. Anode potentials used range from 100 to 250 volts; electron currents range from 0.2 to 2.0 milliamperes. Ionization currents may often be one-thousandth that of the electron current, or less, and so pressures below 0.000001 mm. could be measured rather easily.

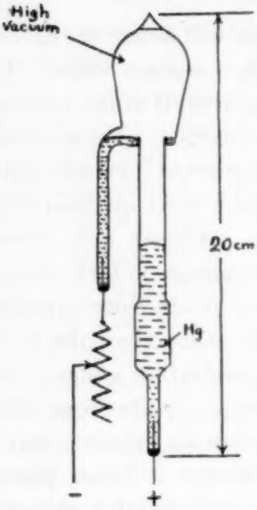
A discussion of high vacuum procedure may seem like making much ado about next to nothing. Studies in vacua, however, led to submolecular magnitudes, and provided many of the facts that led investigators to discard the former ideas of hard atoms. In the vacuum, where we might expect the least knowledge, we have, perhaps, found the most. And there, where now we ought to be able to say we have a clear understanding of all possibilities, there exists still a vast field of unknowns.

Note:—During his address Mr. Manning showed slides picturing vacuum pumps and devices for measuring vacua. For those wishing to look up the subject he recommended "High Vacua," by Dr. Dushman.

After lunch, Mr. Manning gave an exhibition of "Thyratron" tubes, using a special demonstration board. He explained their use for the control of theater lighting, as step down transformers for high tension direct current and as step up transformers in machines for color analysis. He also gave interesting information about the use of the new "Sun Lamp."

INFORMAL DEMONSTRATION OF NEW APPARATUS.

By N. Henry Black,
Harvard University.



Mercury Arc

1. *Cavendish Experiment to demonstrate the attraction of masses.* This apparatus was recently imported from E. Leybold's Nachfolgen at Cologne and is built according to Wulf. The new feature is that the larger masses are rolled back and forth in tempo with the natural swing of the torsion pendulum and so builds up a considerable swing which is easily perceptible with a long light-pointer. (For a good description of this classical experiment see Kimball's College Physics.)

2. *A large photoelectric cell* (made by the General Electric Co.) was connected with a "B" battery (45 volts) and a sensative relay (General Radio Co., No. 431) and so used to ring a gong. The G. E. Co. now makes a smaller photoelectric cell (such as JP 23) which may be used for this experiment.

3. *An impulse balance* (Cenco F 1323) was used to measure the force of small stream of water. This experiment furnishes a method of determining the F in the familiar equation of impulse and momentum, $Ft = Wv/g$.

4. *The bright-line spectrum of the mercury arc* was projected. A home-made vertical mercury arc (Fig. 1) was connected with an adjustable resister of about 50 ohms and 3 amp. capacity to the 110-volt D.-C. line. This arc was enclosed in a metal box with an adjustable slit. Then a sharp image of the slit was projected on the screen with a convex lens of 40-cm. focal length. Finally a 60° glass prism bottle filled with monochlorbenzol (C_6H_5Cl) was placed in front of the lens to disperse the light. The three principal lines in the visible spectrum of mercury were clearly seen on the screen and two more lines beyond the violet could be seen on a fluirescent screen.

5. *Balancing capacity and inductance in an A.-C. circuit to produce resonance.* A variable radio block B condenser (Tobe Deutschmann Co.) of 14 mfd. capacity and a larger inductance coil (Spool 3000 turns No. 16 wire, coil 8.5 in. long, 2 in. internal, 5 in. internal diam.) of about 10 ohms and 0.2 henry with a sliding iron core is connected in series with a 50-watt lamp to 110 volt A.-C. line. By short circuiting the condenser the inductance coil can be used to dim the lamp by sliding the iron bar into the coil. By using about 12 mfd. of the condenser in series with the coil, the condition of resonance can be found by sliding the iron bar part way into the coil. This is indicated by the brightness of the lamp filament.

Note:—Those who stayed for the afternoon session were well rewarded by the opportunity of seeing these demonstrations at close range.

W. W. Obear, Secretary.

THE SIPHON.

By J. C. Packard,

High School, Brookline, Mass.

The following experiments have proved helpful in my classes and therefore may be of use to others.

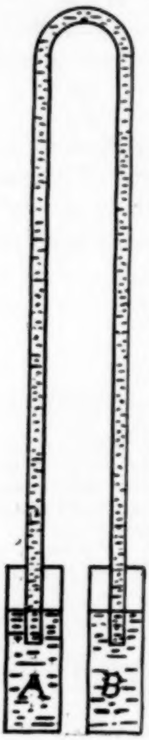


Fig. 1

1. *Preparation.* A long glass tube—the longer the better—bent into the form of an inverted U is supported in such a way that one end of the tube dips beneath the surface of the water contained in a tall glass jar or beaker, while the other end enters an empty beaker of the same size and shape. A tube so placed constitutes a siphon. The siphon is started by exhausting air from the open end of the tube, through a rubber pipe supplied for the purpose, and is allowed to run until the water in the two beakers comes to the same level. What supports the water in the tube? See Fig. 1.

2. *Experiment.* Color the water in one of the beakers (A) red by the use of a few bits of aniline dye and the water in the other beaker (B) blue by the same process. I. Raise the beaker a few inches and the *red* liquid climbs steadily up the tube, pushing the water before it, flows around the bend at the top, and moves steadily down the tube on the other side until it enters the beaker B. II. Lift the beaker B and the *blue* liquid climbs over into A, in apparent defiance of the laws of gravity, pushing the *red* liquid before it. Explain clearly. How high can the liquid be made to rise by this process? How long can the action be kept up? What practical use can be made of this principle?

Look up the self-starting siphon, as found in the hardware stores, for use in removing the "top of the milk" without upsetting the contents of the jar, and explain its action.

Note: Figure 2 represents a modified form of the same experiment, in which the red liquid is made to run slowly along the entire length of the demonstration table in a most spectacular manner. Try it.

3. *Auxiliary.* Place two tumblers side by side, one being empty and the other two-thirds full of water. Secure a piece of cotton wicking, rather loosely woven, about six inches long, and soak it in the water of the tumbler until it is thoroughly

saturated. Pick up one end of the saturated wicking and drop it into the empty tumbler, letting it fall to the bottom, while the other end still remains in the water. What happens after

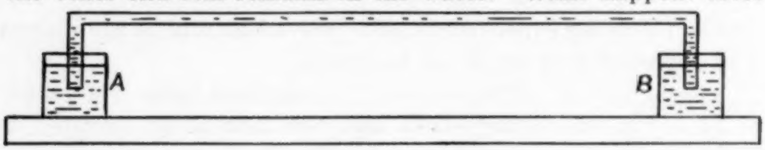


FIG. 2

a minute or two? Does the same principle apply here as in the siphon above, or is a new principle involved? Explain fully. What practical use can be made of such a device? What inconvenience is sometimes occasioned by an unexpected action of this sort?

PROBLEM DEPARTMENT.

CONDUCTED BY C. N. MILLS,
Illinois State Normal University.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to C. N. Mills, Illinois State Normal University, Normal, Ill.

1085. *Proposed by the Editor.*

If perpendiculars be drawn to the sides of a regular polygon of n sides from any point on the inscribed circle whose radius is a, prove

$$\frac{2}{n}\sum\left(\frac{p}{a}\right)^2=3, \text{ and } \frac{2}{n}\sum\left(\frac{p}{a}\right)^3=5.$$

Loney's Plane Trigonometry, problem 27, page 289.

I. Part (a). *Solved by J. F. Howard, San Antonio, Texas.*

Given a regular polygon of n sides, center O, with inscribed circle touching sides of polygon at A, B, C, D, E, and so on. P is any point on the inscribed circle. PX is a $\perp$ from P to one side of the polygon. A pentagon is used for the discussion. Radius of inscribed circle is a.

Draw $\perp$s from O to the sides of the polygon.

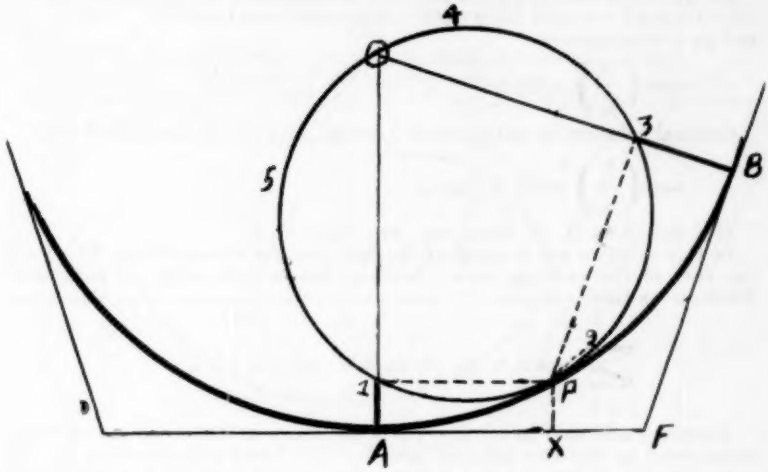
Draw $\perp$s from P to OA, OB, OC, OD, and OE: the feet of the $\perp$s being respectfully, 1, 3, 5, 2 and 4.

Sinces $\angle$s 1, 2, 3, 4, and 5 are right angles, the circle described on OP as a diameter will pass through 1, 2, 3, 4, and 5.

P1 is // to AF; P5 is // to HG. It is easily proven that $\angle 5P1=1/n$ of $2\angle rt.$

Hence arc $51=1/n$ of circumference of circle through 1, 2, 3, 4, 5. Likewise for the arcs, 12, 23, 34 and 45.

$$\begin{aligned} PX &= OA-O1 \\ (PX)^2 &= (OA)^2-2\,OA\cdot O1+(O1)^2 \\ &= (OA)^2-2\,OA(OA-PX)+(O1)^2 \end{aligned}$$



$$\text{sum }(PX)^2 = n(OA)^2 - 2n(OA)^2 + 2\cdot OA \text{ sum }(PX) + \text{ sum }(O1)^2$$

$$\text{sum }(PX) = na.$$

Theorem. The sum of the $\perp s$ to the sides of a regular polygon circumscribed about a circle, from a point within, is equal to n times the radius of the circle.

$$\text{sum }(O1)^2 = 2na^2$$

Theorem. The sum of the squares of lines drawn from any point on circle circumscribing a regular polygon, to the vertices of the polygon is equal to $2n$ times the square of the radius of the circle.

Hence, substituting in the above expression, we get

$$\text{sum }(PX)^2 = na^2 - 2na^2 + 2na^2 + 1/2\ na^2 = 3/2\ na^2,$$

$$\text{or } \frac{2}{n} \text{ sum} \left(\frac{p}{a}\right)^2 = 3.$$

II. *Solved by Norman Anning, University of Michigan.*

(a) With a suitable figure it is easy to establish the following lemmas:

(1) If the arc joining two points on a circle of radius a subtends an angle Z at the center, then the length of the $\perp$ from either point to the tangent at the other point is

$$a - a \cos Z = a(1 - \cos Z).$$

(2) The sum of the projections of the sides of any regular polygon on any line in its plane is zero.

Let the angle X be defined by the relation $nX = 360°$, and let Y be the angle between a radius drawn to the chosen point and a radius drawn to one of the points of contact.

By lemma 1,

$$\text{sum}\left(\frac{p}{a}\right)^2 = 1 - \cos Y + 1 - \cos(X+Y) + 1 - \cos(2X+Y) + \cdots,$$

which by lemma 2 we get $= n + 0$.

$$(1-\cos Y)^2 = 1 - 2\cos Y + \cos^2 Y = 1/2 - 2\cos Y + 1/2 \cos 2Y.$$

$$\begin{aligned}\text{Hence}\quad \text{sum}\left(\frac{p}{a}\right)^2 &= 1/2 - 2\cos Y + 1/2 \cos 2Y \\ &+ 1/2 - 2\cos(X+Y) + 1/2 \cos 2(X+Y) \\ &+ 1/2 - 2\cos(2X+Y) + 1/2 \cos 2(2X+Y) \\ &+ \cdots\cdots\cdots\cdots \\ &+ 1/2 - 2\cos(Y-X) + 1/2 \cos 2(Y-X). \\ &= n \text{ times } 1/2 - 0 + 0 \text{ (By lemma 2).}\end{aligned}$$

Similarly, by use of suitable reduction formulas, we can show that

$$(1-\cos Y)^3 = 5/2 - 15/4\cos Y + 3/2\cos 2Y - 1/4\cos 3Y,$$

and as a consequence

$$\text{sum}\left(\frac{p}{a}\right)^3 = 5n/2.$$

General solution as indicated at bottom page 57, Loney's, 2nd vol.:

$$\text{sum}\left(\frac{p}{a}\right)^k = n(2^{-k})\ (2_k C_k).$$

III. *Solved by H. D. Grossman, Brooklyn, N. Y.*

In this solution use is made of the fact that for the equation $X^n - 1 = 0$, the sum of the roots is zero. Setting this fact in terms of *Demoivre's Theorem* we have

$$\sum_{k=0}^{n-1} (\cos k/n\ 2\text{pi} + i \sin k/n\ 2\text{pi}) = 0,\ n > 1$$

Equating real and imaginary parts we arrive at two expressions which correspond to the two lemmas used by Mr. Anning in Solution II. By summing the trigonometric series involved, the required result is obtained.

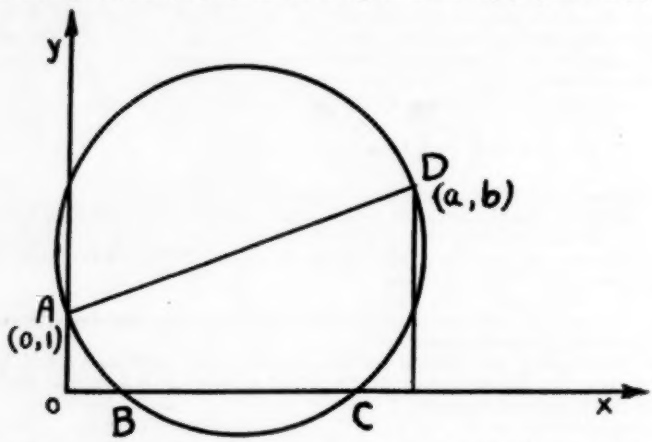
1086. *Proposed by the Editor.*

Using a circle construction, find graphically the roots of

$$x^2 - ax + b = 0.$$

1. *Solved by J. O. Austin, Thebes, Ill.*

In the figure the coordinates of the points are $A(0, 1)$ and $D(a,b)$.



Construct a circle with AD as a diameter. Then the lengths OB and OC are the roots of the given equation.

The equation of the circle on AD is

$$(x - a/2)^2 + \left(y - \frac{b+1}{2}\right)^2 = a^2/4 + \frac{(b-1)^2}{4}.$$

Setting $y = 0$, and combining we get

$$(x - a/2)^2 = (a^2 - 4b)/4$$

Whence,

$$x = \frac{a \pm \sqrt{a^2 - 4b}}{2},$$

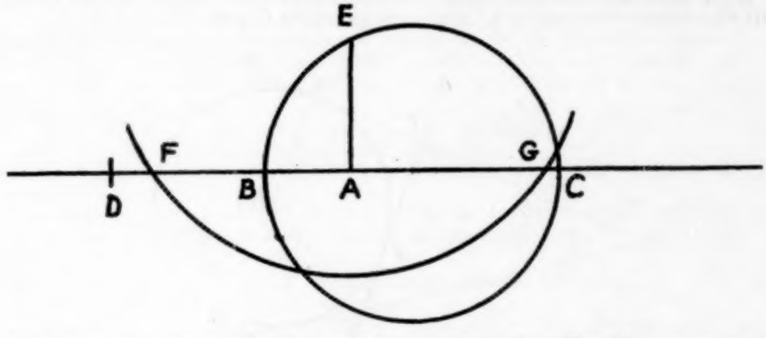
which is the result found by using the quadratic formula.

Editor. Same construction given by *Samuel M. Jenness, Sykesville, Md.*

This is the classic construction which has an interesting history.

II. Solution by *Smith D. Turner, Baytown, Texas* (two solutions).

On a line mark AB = 1, AC = b, and AD = $a/2$. On BC as a diameter,



draw a circle. Draw $\perp$ at A, cutting circle at E. With E as a center, and radius $a/2$, draw arc cutting line at F and G. Then lengths of DF and DG are the required roots.

Proof. AE = square root of (1xb); AG = AF = $\sqrt{(FE)^2-(AE)^2}$.
$= \sqrt{a^2/4-b}$

DF = DA − FA. Hence,

$DF = a/2 - \sqrt{a^2/4-b}$.

$DG = a/2 + \sqrt{a^2/4-b}$.

Also solved by *J. F. Howard, San Antonio, Texas;* and *A. J. Patterson, Wheeling, W. Va.*

1087. *Proposed by Norman Anning, University of Michigan.*

The numbers a, b, c and d are all different and satisfy the equations: $ac=b^2$, $bc=ad$, $cd=10ab$. Find the numerical value (or values) of c^3/abd).

I. *Solved by A. J. Patterson, Wheeling, W. Va.*

(1) $ac=b^2$; (2) $bc=ad$; (3) $cd=10ab$.

(4) $abdc^3=10a^2b^3d$, multiply (1), (2), (3).

(5) $c^3/abd=10b/d$, divide (4) by $a^2b^2d^2$.

(6) $d/b=10b/d$, divide (3) by (2).

(7) $d^2=10b^2$, from (6).

(8) $d=b\sqrt{10}$, from (7).

(9) $c^3/abd=10b/b\sqrt{10}=\sqrt{10}$, substitute (8) in (5).

II. *Solved by Russell N. McKenzie, Owen Sound, Ontario.*

From (1), $b/a=c/b$; from (2), $b/a=d/c$. Hence, $b/a=c/b=d/c$. Therefore a, b, c, and d are in geometric progression. $a=a$, $b=ar$, $c=ar^2$, and $d=ar^3$. Substituting in (3) gives $a^2r^5=10a^2r$, then $r^4=10$; whence $r^2=\pm\sqrt{10}$; therefore $c^3/abd=a^3r^6/a^3r^4=r^2=\pm\sqrt{10}$.

III. *Solved by the Proposer.*

$ac=b^2$
$ac=b^2$
$bc=ad$, then $a^2b^3dc^6=10a^4b^5d^3$, from which the required re-
$bc=ad$ sult is easily obtained.
$bc=ad$
$dc=10ab$

Also solved by *Agnes MacNeish, Chicago, Ill.; J. F. Howard, San Antonio, Texas; Bessie Jordan, Hendersonville, North Carolina; Louis R. Chase, Newport, R. I.; A. E. Pitcher, Cleveland, Ohio; B. R. Bentley, Redwood City, Calif.; Smith D. Turner, Baytown, Texas; T. A. Bickerstaff,*

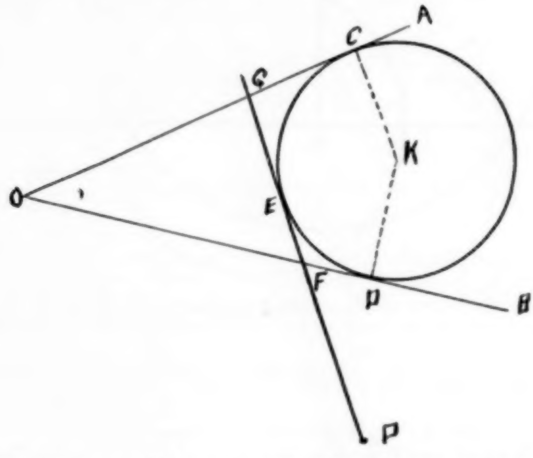
University of Miss.; Alfred Green, Spokane, Wash.; and Floyd Hanson, Wilmore, Kansas.

1088. *Proposed by J. F. Howard, San Antonio, Texas.*

Given OA and OB two lines from O; P is any point. Through P draw a line forming a triangle with intercepts on OA and OB, such that the perimeter of this triangle shall be equal to a given line.

Solved by A. J. Patterson, Wheeling, W. Va.

Let L represent the given perimeter of the triangle. Mark on OA and OB the distances equal to L/2, obtaining points C and D.



At C and D draw $\perp$s which meet at K. With K as a center draw a circle tangent to OA and OB, at C and D respectively. Through P draw a line tangent to the circle, which will cut OA and OB at G and F. The line PFG is tangent to the circle at E. OFG is the required triangle.

Proof. $CO+DO=L$. $CO+DO=OG+GF+OF$, since $GC=GE$, $FD=FE$. Also solved by the *Proposer.*

1089. *Continued solution of* 1050.

In the printed solution of 1050, April, 1929, page 422, there is no proof that all the coefficients shall be integers. Give a proof that all the coefficients shall be integers in the expansion of $\sqrt{1-4x}$.

Solved by H. D. Grossman, Brooklyn, N. Y.

The general term in the expansion, disregarding the sign, is

$$\frac{4^n\cdot 1\cdot 3\cdot 5\cdots\cdots(2n-3)}{2^n\cdot 1\cdot 2\cdot 3\cdots\cdots(n-1)n}.$$

The total power of 2 in the denominator is

$n+n/2+n/4+n/8+$to a finite number of terms.

This sum is less than $2n$, the power of 2 in the numerator.

To prove the same for odd primes we recall that

$$\begin{bmatrix} r+k \\ r \end{bmatrix}=\frac{(r+1)(r+2)\cdots\cdots(r+k)}{(1\cdot 2\cdot 3\cdots\cdots k},$$
$$=\frac{(r+1)p\cdot(r+2)p\cdots\cdots(r+k)p}{p\cdot 2p\cdots\cdots kp}$$

is an integer, i.e., that the product of the first k multiples of p divides the product of any successive k multiples of p.

The coefficient of x^n may be written

$$2\cdot\frac{(n+1)(n+2)\cdots\cdots\cdots(2n-3)(2n-2)}{2\cdot 3\cdots\cdots\cdots(n-2)(n-1)}.$$

Consider only the fraction that multiples 2. For every odd prime p that does not divide n, the denominator does not contain a higher power of p than the numerator, for

$$\frac{n(\text{numerator})}{\text{denominator}} = \left[\frac{(2n-2)}{n-1}\right] = \text{an integer.}$$

Consider then any odd prime p that does divide n. Since p is greater than 2, the multiples of p that occur in the denominator are its first $(n-1)/p$ multiples. It remains only to show that the numerator contains an equal number of multiples of p; this we do by effecting a one-to-one correspondence between the multiples of p in the denominator and those in the numerator. Since p divides n, it cannot divide $(n-1)$. For $2 < kp \leq (n-2)$, where

$$k = 1, 2 \ldots\ldots\ldots\ldots (n-1)/p.$$
$$n+2 < n+kp < 2n-2.$$

Thus we may associate with every kp in the denominator its $n+kp$ in the numerator.

Comment by Mr. Anning. The fact that all binomial coefficients are integers can be established by mathematical induction (See Chrystal Algebra, vol. II, p. 530).

1090. *Proposed by S. Chuang, Ping-yang-fu, Shansi, China.*

Solve the following system of equations:

$$xyz = x+y+z$$
$$x^2y^2z^2 = x^3+y^3+z^3,$$
$$x-y-z = .0$$

Solved by Ruth W. Bortz, Ardmore, Pa.

Number the given equations (1), (2) and (3).

(4) $xyz = 2x$, add (1) and (3).

Hence, $x=0$ is one value of x.

Then $yz=2$, and $y^2z^2=4$.

$4x^2 = x^3+y^3+z^3$, substitute in (2).

$x(4x-x^2) = (y+z)(y^2-yz+z^2)$

From (3), $x=y+z$, then

$$\begin{aligned} 4x - x^2 &= y^2 - yz + z^2 \\ x^2 &= y^2 + 2yz + z^2 \\ \hline 4x - 2x^2 &= -3yz. \end{aligned}$$

Since $yz=2$, $4x-2x^2=-6$, then $x=3$ or -1.

Using these two values of x in (3) we get after solving with $yz=2$ the corresponding values of y and z. Hence

$$x = 3,\ 3,\ -1,\ -1,\ 0,\ 0$$
$$y = 1,\ 2,\ \frac{-1-\sqrt{-7}}{2},\ \frac{-1+\sqrt{-7}}{2},\ -\sqrt{-2},\ \sqrt{-2}$$
$$z = 2,\ 1,\ \frac{-1+\sqrt{-7}}{2},\ \frac{-1-\sqrt{-7}}{2},\ \sqrt{-2},\ -\sqrt{-2}$$

Also solved by *T. A. Bickerstaff, University, Miss.; Rudolph Jandl, Spokane, Wash.; Lorens Carlson, Malino, Sweden; Norman Anning, University of Michigan; A. J. Patterson, Wheeling, W. Va.; Smith D. Turner, Baytown, Texas; Agnes MacNeish, Chicago, Ill.; W. O. Sisk, Mineral Wells, Texas; J. F. Howard, San Antonio, Texas; and George T. Johnson, Brainerd, Minn.*

PROBLEMS FOR SOLUTIONS.

1103. *Proposed by W. E. Buker, Leetsdale, Pa.*

Find integral values of X and Y which satisfy the relation

$$A^x + (A+1)^x + (A+2)^x + \ldots\ldots\ldots + (A+B)^x = (A+B+1)^x$$

1104. *Proposed by Paul Mount-Campbell, Monte Vista, Colo.*

Find the volume of the solid resulting from a ten centimeter cube by a plane. The cutting plane makes an angle of 45° with the base plane.

The line of intersection of these two planes passes through a vertex of the base and is perpendicular to a diagonal drawn to this vertex.

1105. *Proposed by Raymond Huck, Johnson City, Ill.*

A right circular cone formed by removing a sector from a circular disc of radius R is set on a sphere of diameter R, the volume included between the sphere and the cone being a maximum. Determine the number of degrees in the sector removed.

1106. *Proposed by the Editor.*

A counterpoise on a wheel of an engine has the shape of a crescent and fits inside the rim of the wheel 8 feet in diameter. The crescent subtends an angle of 120° at the center of the wheel. The center of the circle determined by the inner rim of the crescent is on the rim of the wheel. Find the distance of the center of gravity of the counterpoise from the center of the wheel.

1107. *Proposed by the Editor.*

A 1 lb. sample of milk tests 3 1/2 per cent butter fat. How much cream, testing 35 per cent butter fat, must be added in order to bring the milk to a 5 per cent standard? (Do not use Algebra.)

1108. *Proposed by T. A. Bickerstaff, University, Miss.*

When I was born, my sister was 1/4 as old as my mother. She is now 1/3 as old as father. In four years, I shall be 1/4 as old as father. I am now 1/4 as old as mother. Which two members of our family have the same birthday?

PRECISION IN THE USE OF TERMS—IN SCIENCE TEACHING[1].

By J. O. Frank,

Professor of Science Education, State Teachers College, Oshkosh, Wis.

Supervisors of science teaching in city school systems, state high school inspectors and other supervising teachers often try to classify science teachers—on basis of remedial training needed. One scheme of classification provides for the following types of teachers:

(1). Teachers who need further instruction in the fundamentals of science—who need background. (Instruction in fields other than that in which they are teaching.)

(2). Teachers who need further instruction in the science they claim as their field—as well as in other sciences.

(3). Teachers who do not need further preparation in the field of science—but who do need instruction in methods of teaching and in the general field of education.

(4). Teachers who are well qualified in the field of science and who have a working understanding of the principles of modern educational practices—but who are not precise and discriminating in the actual treatment of the subject matter of science.

Much has been said and written about the first three types of teachers and the training they need—but little has been said about the last type of teacher described, though certainly remedial treatment is indicated.

For purposes of identification, especially of self identification, the following description may be of some assistance to teachers who are interested in trying to discover the careless though competent teacher.

This teacher will be found to be unable to state clearly many of the fundamental facts of science—he has not been trained to be precise and shows it in all places where something near the truth will suffice—where a general statement of a truth well understood can be substituted for a required precise statement of a fact—not understood.

There are other earmarks, but one distinguishing trait is to be noted—this teacher seems to have a lack of appreciation for *precision*, and this lack can be seen in his choice of words, choice of illustrations of fundamental laws, in his way of stating facts,

[1]From an address before the General Science Section of the Wisconsin State Teachers' Association, Milwaukee, Wis., Nov. 7, 1929.

in his failure to make and use precise definitions; and in general, in his failure to make reasonably fine discriminations.

For some teachers who want to test themselves, a test has been devised.* It is offered merely to illustrate what has been told above.

Take the following list of pairs of words and with pencil and paper write out the distinguishing differences between the meanings of the words in each pair. These are examples of pairs of words which are frequently misused in high school science. They are all words which every high school science teacher, regardless of his special field, ought to be able to use with precision.

1.	absorb	adsorb	18. inclination	declination
2.	adhesion	cohesion	19. inertia	momentum
3.	adulterant	impurity	20. lye	lime
4.	body	substance	21. meteor	meteorite
5.	component	constituent	22. mineral	ore
6.	contagious	infectious	23. mixture	compound
7.	decay	putrefy	24. nutrient	nutriment
8.	diffraction	refraction	25. photomicrograph	microphotograph
9.	disinfectant	antiseptic		
10.	effervescence	efflorescence	26. precision	accuracy
11.	ether	petroleum ether	27. rotation	revolution
12.	force	power	28. sublimation	volatilization
13.	gas	vapor	29. translucent	transparent
14.	germicide	insecticide	30. union	compound
15.	gravity	gravitation	31. vertical	perpendicular
16.	gum	resin	32. weight	mass
17.	hydroxide	hydrate		

If you can distinguish clearly between the meanings of the words in each pair, you are probably to be considered capable of precise teaching; if you cannot, a little home study with a good dictionary would not be entirely out of place.

*This list of words was compiled from a study of the mistakes made by teachers in the writer's classes over a period of five years.

A HIGH SCHOOL ACHIEVEMENT TEST.

W. W. D. Sones, Professor of Education and Director of Erie Center, University of Pittsburgh and David P. Harry, Jr., Associate Professor of Education, Graduate School, Western Reserve University are the authors of a test for evaluating pupil achievement in the high school. By many pupils and perhaps also by their parents a high school course consists in acquiring a definite minimum number of credits rather than in gaining certain abilities, skills, attitudes and information. In order to correct this misconception and to direct attention to the real purpose of secondary education, the authors have constructed a test to measure the student's ability to reason correctly on questions based on the information obtained throughout the high school period. The test covers English, mathematics, natural science and social studies and is divided into Form A and Form B. World Book Company, Yonkers-on-Hudson, New York.

Modern Junior Mathematics

By Marie Gugle

Assistant Superintendent of Schools
Columbus, Ohio

Book I, 310 plus xxii pages; cloth 80c.
Book II, 230 plus xiv pages; cloth 90c.
Book III, 298 plus lvii pages; cloth $1.00.

This course is in three parts, each being suited to a year's work. It begins with the Seventh Grade and concludes with the Ninth. Starting with simple problems in everyday business and gradually leading the pupil through algebra and the principles of geometry, the course unfolds in a manner that is true to logic and sound pedagogy. The skillful processes employed in correlating the three subjects give mathematics a rank with the animated subjects. It is just the course to develop more uniform results, to make the pupil feel that he must go on to high school, and to inculcate that breadth of vision which enables him to see how mathematics functions in the work of the world. It helps him, more than any other procedure, to convert vague possibilities into happy realities!

SEVENTH YEAR—BOOK ONE

Trains the pupil in the simplest application of arithmetic to business—Develops skill in rapid calculation —Develops the habit of checking—Encourages thrift by making of budgets, etc.—Trains the pupil in the simplest elements of bookkeeping.

EIGHTH YEAR—BOOK TWO

Gives the pupil practical applications in mensuration —Trains the hand to use simple drawing instruments —Familiarizes the pupil with common geometric forms and terms—Introduces algebraic impressions in a natural way.

NINTH YEAR—BOOK THREE

Extends the pupil's knowledge of algebra to negative expressions—Makes the equation so familiar that he uses it naturally as a convenient tool—Enables him to make and interpret formulas—Gives a glimpse into trigonometry and the labor-saving device in logarithms.

THE GREGG PUBLISHING COMPANY

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THE STRANGE CASE OF SUBTRACTING A NEGATIVE NUMBER.

By Barnet Rudman,
South Boston High School, Boston, Mass.

That beginners in Algebra react rather slowly to negative numbers will hardly be disputed by teachers of experience. Particularly subtraction causes many a freshman to sit up and shrug his shoulders. The teacher may argue his case with much eloquence, but in the end pupils find it hard to believe that subtracting -20 from 30 gives 50. If the disbelief becomes at all articulate, the conscientious teacher in despair gropes for further illustrations until his inquisitors are convinced or, as is more often the case, are ready to accept the rules on authority. This to the teacher is a strategic concession of major importance for, the rules of subtraction once established, he can hurry over multiplication and division, and the foundation is complete for the whole superstructure of Algebra.

Because negative numbers are at once fundamental and difficult writers of the newer textbooks have striven valiantly to give the subject adequate treatment. Their success has been considerable. The algebraic scale, the thermometer, north and south latitudes, east and west longitudes, gain and loss, and sundry other "opposites" have been used effectively to impress on pupils the meaning of negative numbers. No such success, however, attended their efforts to render subtraction of negative numbers palpable. The tendency in teaching subtraction has been to (1) define subtraction in terms of addition and derive a law of signs from that readily enough established for addition, or (2) revert to the number scale on which line segments and directions are manipulated to elicit from the pupils the correct conclusions. Neither, in the opinion of the writer, is sufficient as an explanation of the "why" in subtraction, nor even is the combination of both entirely adequate. The first appears to the pupil arbitrary and too abstract to make contact with his past experiences. Algebraically one does add 50 to -20 to get 30, but wherein does common sense sanction the subtraction of something from 30 to the end of obtaining an increase? Subtracting a liability makes one richer, to be sure, but is he not sufficiently enriched in not having to meet his note? Why add another $20 sum to his assets? The second method, that based on the number scale, appeals to none but those able to see their numbers as lines (of such there are but few in a class). The transfer from the ther-

SPENCER BUFFALO U.S.A.

mometer to matters of money and other non-linear situations, if left to the student, will never be made. And, if the teacher undertakes to show the connection, he may run into more complications than he bargained for. The question generally asked by the clear-minded pupil is this: A man has thirty dollars and owes somebody twenty dollars. The debt is canceled (subtract -20). Where in the name of common sense does the man get his fifty dollars?

There is a suggestion in Schultze's "Advanced Algebra" that proved very helpful to the writer. The method somewhat elaborated makes its appeal to the pupil's most elementary number-notions. Let it be required to subtract -3 from 5. The pupils are asked to think of 5 as the sum of five positive units ($+1+1+1+1+1$). Likewise -3 is to be thought of as $-1-1-1$. The three negative units are to be taken from five positive units, an operation that appears impossible because of the dissimilarity in the units of the subtrahend and minuend. To get around this difficulty the minuend is changed in form to include a sufficient number of negative units for the operation to be possible, thus $+1+1+1+1+1+1+1+1-1-1-1$. Even the slowest pupil can now take away -3 (three negative units) and get 8 as a result. The skeptics in the class may at first look askance at the attempt to write 5 in the form $+1+1+1+1+1+1+1+1-1-1-1$ but the simplicity of the scheme soon wins them over. To show that the rule for subtraction is reasonable in the case of $-3-(-5) = +2$, -3 is written as $-1-1-1-1-1+1+1$, and when five negative units are taken the result is two positive units.

The method may be extended to explain the good fortune of the man whose assets have increased from \$30 to \$50 simply because a liability of \$20 had been subtracted. To have \$30 in clear assets and to be able to designate them his own, the man must have had \$20 in reserve against his liability of the same sum. But when the debt was canceled or subtracted or taken away (call the operation what one may) the \$20 held in reserve became available for the man's unconditional use and could be added as assets to his other funds. Or, the man's absolute possession previous to the cancellation of the note amounted to $30+20-20$. Take away -20 and the result is 50.

"Outside activities, over-emphasis on memory work and cramming are the outstanding evils of the American system of education today."

SCIENCE QUESTIONS.

Conducted by Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

Readers are invited to propose questions for solution or discussion—scientific or pedagogical—and to answer questions proposed by others or by themselves.

Please send examination papers on any subject or from any source to the Editor of this department.

What have you got? Send them in.

What would you like? Ask for it.

AN OLD MONKEY PROBLEM.

(Who Gets the Editor's Dollar.)

546. A rope hangs over a pulley. A 10 pound monkey grabs one end of the rope and starts to climb. A 10 pound weight is fastened to the other end of the rope. What happens?

[The *Editor* of this Department will send one paper "Smacker" to the student who will send in the best answer based on experiment. What about using the rope and pulley from the hay fork with a bag of sand equal to the weight of the boy who tries the experiment?]

Which? How? Why?

547. Does dew *rise* or *fall*?

Promises.

541. *Miss Sylvia Erdman, Keno, Oregon, asks for a complete set of Edison's Questions.*

In February, 1930, the *Editor* of this department will publish **Edison's Examination Questions** complete.

538. *Completion Tests by Gordon E. Highriter.*

The tests on Electricity will be continued in February or March. Watch for them.

Is Science in Iowa Dead or Sleeping?

The Hawarden High School Physics Class has not asked a question this fall. Why not, Mr. Lloyd Knox and Miss Katherine Delperdang. Where is The Girls Algebra Society?

GENERAL SCIENCE TESTS.

542. What about Questions in General Science?

The other day a supervisor and head of the General Science Department in a large high school asked the above question of the *Editor*.

542. 1. Do you give examinations on the entire subject?

2. Do you divide the subject into units and give a test on each one?

3. Do you use a "standardized" test? (If so, what tests?)

4. Don't you think the College Entrance Examination Board ought to give an examination on General Science?

5. What do you think about the whole subject?

6. What is your practice?

7. Send in some examinations or test questions.

Miss Burres Sends Answer.

At West Technical High School, Cleveland, we divide the subject of General Science into units and give a test at the completion of each unit. All teachers use the same unit division and give the same tests to their pupils.

The following test was given to 9B boys:

9B Boys Test—West Technical High School, Cleveland, Ohio.

IV. Atmosphere and Oxidation.

Teacher...Name......................Grade........

1. Of what is air composed?
2. Where is air found?

3. Sound is carried thru the............................., and travels in
4. A physical change is one in which
5. A chemical change is one in which
6. Oxidation is
7. Combustion is
8. Why do you use "kindling" to start your furnace?
9. How can you keep your furnace from smoking?
10. When oxidation occurs, the product formed is called
11. How can you prevent oxidation?
12. How does exercise affect oxidation in your body?
13. What proofs have you that oxidation is occurring in the human body?
14. Where does oxidation occur in the animal body?
15. What mechanism for breathing do you find in plants? How do fish breathe?
16. How can you prove that water contains Oxygen?
17. Name three evils caused by breathing through the mouth.
18. What do you mean by ventilation?
19. Why should sleeping rooms be *very* carefully ventilated?
20. Two methods of extinguishing fires are by
21 Explain why fire is extinguished in each of the above
22. What causes the disagreeable smell in poorly ventilated rooms?
23 What should you do first in case you discover a person who has been overcome by gas?
24. Name four ways you can improve your own health as suggested by the work on atmosphere.
25. Describe an experiment which would prove that air does work.

548. Who Else Has a General Science Test?

THEY LIKE TO FOOL WITH MONKEYS.

Dave Cervin of Rock Island started it all over again by proposing "Another Monkey Problem" in December, 1929 (SCHOOL SCIENCE AND MATHEMATICS, page 990).

544. *Dave Cervin's Monkey Problem.*

Here is the problem: *Five* men and a monkey were marooned on an island. They spent the first day in gathering cocoanuts. It happened that each sailor mistrusted the others, so each one stole out alone during the night to get his share. Each divided the pile he found into five equal parts and hid his share. In each case there was one odd cocoanut which was given to the monkey. On the following day they met and divided the remaining pile into *exactly five equal* piles. How many cocoanuts were there in the original pile?

There are two solutions to this problem that I know of, but, unlike the answers to Hollister's cocoanut puzzle, they seem to bear no relationship to each other. Here they are:

a)3121 b)49996

Norman Anning, University of Michigan, says:—

Dear Mr. Jones:—I suppose the way to get finished with the monkey problems is to do them. Am enclosing a solution of the most recent. The details which I have omitted may be found in the chapter on indeterminate equations in any good algebra textbook. Sincerely yours, Norman Anning.

544. *Solution by Norman Anning, Ann Arbor, Mich.*

Suppose there were x cocoanuts.

If there had been $(x+4)$, the first sailor could have taken one more and left four more than he did. Then the second could have taken one more and left four more than he did. And so on to the fifth. In this case there would have been none for the monkey but a live monkey on a cocoanut island is not in need of pity. The number that would remain for distribution in the morning is greater by 4 than an exact multiple of 5, is then $(10y+4)$ or $(10y+9)$ where y is some positive integer. But this number is equal to $(x+4)$ multiplied by (four-fifths)^5. Consequently

$$1024\ (x+4)/3125 = 10y+4, \text{ or } 10y+9.$$

The $(10y+9)$ is barred because it would lead to the absurdity: even = odd. Use of the other leads to the equation

$$512x-15625y=4202$$

which must be solved in positive integers. Standard algebraic methods lead to the solutions

$$x=3121+15625t,$$
$$y=102+512t,$$

where $t=0, 1, 2, 3,$ ....

There are also solutions from George E. Hudson, Room 1213 Navy Department, Washington, D. C., and Glenn F. Hewitt, 4942 N. Kedzie Ave., Chicago, Ill. Both are good. (I'll publish one or both in another number.—JONES.)

THE EDITOR WORRIES.

I'm worrying about the *size* of pile containing 49,996 cocoanuts. How could *one sailor* (let alone *five*) pile and re-pile that many cocoanuts in one night?

549. How much does a cocoanut weigh?
How much *work* did the first sailor do?

Send Your Picture.

Packard of Brookline sends me a thumbnail picture of himself and says, "Send me a snap shot or something that I may know how you look?"

That's an idea. Let other contributors send in small pictures of themselves and maybe we can get them published.

How do you look, anyway.

BOOKS RECEIVED.

Physics of the Home, A Textbook for students of Home Economics by Frederick A. Osborn, Professor of Physics, University of Washington. Second Edition. Cloth. Pages xiv+397. 13.5x20.5 cm. 1929. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York. Price $3.00.

Practical Chemistry by Lyman C. Newell, Professor of Chemistry, Boston University, Boston, Mass. Revised Edition. Part I. Cloth. Pages viii+543. Part II. Pages viii+168. 12.5x18.5 cm. 1929. D. C. Heath and Company, 285 Columbus Ave., Boston, Mass.

Animals Looking at You by Paul Eipper, Photographs by Hedda Walther. Cloth. 163 Pages. 15x23.5 cm. 1929. The Viking Press, 18 East 48th Street, New York. Price $3.00.

New Laboratory Experiments in Practical Physics to accompany Black and Davis' "New Practical Physics" by N. Henry Black, Assistant Professor of Education, Harvard University. Cloth. Pages ix+263. 12x19 cm. 1929. The Macmillan Company, 60 Fifth Avenue, New York. Price $1.12.

Seventh-Year Mathematics by Ernest R. Breslich, Associate Professor of Teaching of Mathematics, The College of Education, The University of Chicago. Cloth. Pages xi+284. 12.5x19 cm. 1929. The Macmillan Company, 60 Fifth Avenue, New York. Price 96 cents.

Instructional Tests in Biology, Comprising Twenty-five Tests in Animal, Human, and Plant Biology for Junior and Senior High Schools by J. G. Blaisdell, Chairman Biology Department, Charles E. Gorton High School, Yonkers, New York. Paper. Pages viii+56. 16x25.5 cm. 1929. World Book Company, Yonkers-on-Hudson, New York.

A Source Book in Mathematics by David Eugene Smith, Professor Emeritus in Teachers College, Columbia University, New York City. First Edition. Cloth. Pages xvii+701. 14.5x23 cm. 1929. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York. Price $5.00.

A Chemical Dictionary by Ingo W. D. Hackh, Professor of Chemistry, College of Physicians and Surgeons, San Francisco, Calif. Cloth. Pages viii+790. 232 Illustrations and over 100 Tables. 16.5x24.5 cm. 1929. P. Blakiston's Son and Company, Inc., 1012 Walnut Street, Philadelphia, Pa. Price $10.00.

The Terminology of Physical Science by Duane Roller, Professor of Physics, The State University of Oklahoma, Norman, Oklahoma. Paper. 115 Pages. 13x21 cm. 1929. The University of Oklahoma Press, Norman, Oklahoma. Price $1.00.

Organic Evolution by Richard Swann Lull, Sterling Professor of Vertebrate Paleontology, Director of the Peabody Museum of Natural History, Yale University. Revised Edition. Cloth. Pages xix+743. 14x21.5 cm. 1929. The Macmillan Company, 60 Fifth Avenue, New York. Price $4.50.

Experimental Science by A. Frederick Collins. Illustrated by the author. Cloth. Pages xvi+280. 12.5x18.5 cm. 1929. D. Appleton and Company, 35 West 32nd Street, New York. Price $2.00.

Some Universal Principles of Communication by John Mills, Director of Publications, Bell Telephone Laboratories. Paper. 12 pages. 15x23 cm. 1929. Bell Telephone Laboratories, Inc., 463 West Street, New York.

State School Taxes and School Funds and Their Apportionment by Fletcher Harper Swift, Professor of Education, University of California and Bruce Lewis Zimmerman, Research Assistant in Education, University of California. Department of the Interior, Bureau of Education, Bulletin, 1929, No. 29. Paper. Pages viii+431. 15x23 cm. United States Government Printing Office, Washington, D. C. Price 50 cents.

The American Handwriting Scale with Manual and Record Blank by Paul V. West, School of Education, New York University. The A. N. Palmer Company, 55 Fifth Avenue, New York.

Collection and Preservation of Insects for use in the Study of Agriculture by Margaret C. Mansuy, Senior Scientific Aid, Taxonomic Unit, Bureau of Entomology. U. S. Department of Agriculture, Farmers Bulletin No. 1601. Paper. 20 pages. 15x23 cm. U. S. Department of Agriculture, Washington, D. C. Price 5 cents.

Connecticut Geological and Natural History Survey, 1927-1928. Bulletin No. 45. W. E. Britton, Superintendent. State Librarian, Mr. George S. Godard, Hartford, Connecticut. Free to Public Libraries, Colleges, Scientific Institutions and to scientific men and teachers. Price to others 10 cents.

BOOK REVIEWS.

Plane Trigonometry, by Ernest Jackson Oglesby and Hollis Cooley, Department of Mathematics, Washington Square College, New York University. Pp. ix+150+76. 15x23 cm. 1929. Prentice Hall, Inc., 70 Fifth Avenue, New York. Price $1.60.

In this book, whenever practicable, new topics have been introduced by means of preliminary questions and exercises. This procedure has been adopted for the purpose of relating the new material to that with which the student is familiar, strengthening the student in the ability to think for himself, and directing him away from the notion that the subject is purely formal.

The trigonometric functions of the general angle are introduced at the beginning. At the introduction of the general treatment of the triangle the four cases are discussed with reference to the law of sines. The student is led to see that this law can be used to the best advantage in solving only two of the cases. In addition to the usual applications to surveying, mechanics, and so forth, we find applications to polar coordinates and complex numbers. J. M. Kinney.

Modern Geometry, An Elementary Treatise on the Geometry of the Triangle and the Circle, by Roger A. Johnson, Associate Professor of Mathematics, Hunter College of the City of New York, under the Editorship of John Wesley Young, Professor of Mathematics, Darmouth College. Pp. xiii+319. 12x29 cm. 1929. Houghton Mifflin Company, 2 Park Street, Boston. Price $3.50.

In recent years interest in the so-called modern geometry which was cultivated extensively during the latter half of the nineteenth century

has again revived. This revival of interest is probably due to the feeling that teachers of secondary mathematics need a more extended background in the geometric field.

This book will appeal to at least four different classes of students: (1) Teachers of secondary mathematics, (2) Students in normal schools and colleges, who are preparing to teach mathematics, (3) The general student interested in mathematics, (4) the mathematician, who can use it as a book of reference. J. M. Kinney.

Elements of the Differential and Integral Calculus, by William Anthony Granville, formerly President of Gettysburg College. Revised by Percy F. Smith and William Raymond Longley, Professors of Mathematics at Yale University. Pp. x+516. 16x24 cm. 1929. Ginn and Company. Price $3.20.

This is a revision of the widely used Granville Calculus. The following features deserve mentioning:

1. The book as a whole is a work of art. There are numerous excellent drawings and the typography is attractive.
2. There is an abundance of practice material and applied problems.
3. The text is carefully written and easy to read. J. M. Kinney.

New Laboratory Experiments in Practical Physics, by W. Henry Black, Assistant Professor of Education, Harvard University. Pages viii+167. 20x27 cm. 1929. The Macmillan Company.

This book is a revision of Laboratory Experiments in Practical Physics by the same author which was published six years ago, several improved editions having appeared in the meantime. The last edition appears in both bound and loose leaf form and contains, in addition to the original sixty-five experiments, six "*Supplementary Experiments*" which, although of more advanced nature, are well within the grasp of a brilliant student.

This laboratory manual, which it must be remembered is intended for high school students or for college students who have not had high school physics, is a book of unusual merit. It contains a sufficiently large number of experiments to give the instructor a great variety of choice. Many of these experiments require only simple and inexpensive instruments so that the manual can be adapted to almost any laboratory equipment, no matter how mediocre. Each experiment contains detailed and clear instructions in regard to both the purpose of the experiment and the method of procedure. Carefully drawn explanatory diagrams are of great help to both instructor and student. The tables accompanying a great number of the experiments are of great assistance to the student in familiarizing him with the proper tabulations of the results.

There is no doubt in the writer's mind that this manual, together with the text book by the same author, is one of the most powerful instruments we possess in this country for the teaching of elementary physics.

Ph. A. Constantinides.

Physics of the Home, A Textbook for students of Home Economics by Frederick A. Osborn, Professor of Physics, University of Washington. Second Edition. Cloth. Pages xiv+397. 13.5x20.5 cm. 1929. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York. Price $3.00.

Increase in the quantity of physics subject matter has been so great in the twentieth century that it is no longer possible to establish a basic course suitable for all curricula and leave any time for study of special topics. Hence in building a physics course for a restricted group of students selection of principles to be studied is as important as selection of applications to be used for illustrating the principles. This is the proposition which has guided the author in this book. It employs no new method of presentation: descriptive and explanatory paragraphs are followed by illustrative problems and by rather unusually long lists of practice or home study questions and numerical problems. It is very decidedly not an attempt to present a soft course, as is sometimes assumed to be the case when physics for specialized groups is mentioned. The author

suggests that the book was written to be used as a basis for the work of two quarters in college but is not too difficult for a full year course in high school.

The following table will show its content compared to the average content of two widely used texts in general college physics and to the average of two recent high school texts:

Percentage by pages devoted to the Five Major Divisions.

Divisions	Physics of the Home	Average of Two College Texts	Average of Two H. S. Texts
Mechanics	26.6%	31.0%	36.4%
Sound	4.9%	10.2%	7.3%
Heat	27.0%	12.5%	15.6%
Light	27.3%	18.2%	13.8%
Electricity	17.3%	28.1%	26.8%

This table shows a considerable shift in emphasis from mechanics, sound and electricity to heat and light. The other essential difference between this text and textbooks of general college physics is that this book draws its applications and illustrations almost entirely from the home.

This is the second edition of the book but no very radical changes have been made in the revision. It merits the attention of teachers of physics for home economics students and of physics classes for girls in secondary schools. It is excellent as a reference book for all high schools.

G. W. W.

Experimental Science by A. Frederick Collins. Illustrated by the author. Cloth. Pages xvi+280. 12.5x18.5 cm. 1929. D. Appleton and Company, 35 West 32nd Street, New York. Price $2.00.

This is another of the very interesting books by Mr. Collins, written for the entertainment and instruction of young and old. It does not tell new things but describes and explains old tricks in language easily understood. All of the experiments or demonstrations may be performed with inexpensive or home-made apparatus. The book contains many suggestions for the physics and general science classes and for science club programs. It should be in every school library. The principal topics treated are balancing feats, tops and gyroscopes, air phenomena, water phenomena, soap bubbles, sound experiments, light and color demonstration, heat and temperature tricks, and electrical experiments.

G. W. W.

The Teaching Unit, A Type Study, by Douglas Waples, Professor of Educational Method, University of Chicago, and Charles A. Stone, Instructor in Mathematics, University High School, Chicago. Cloth. Pages x+205. 10x15 cm. 1929. D. Appleton and Company. $2.00.

The authors present a method for organizing work into units and finding the difficulties in the unit. Directions are given for determining what the unit should contain by consulting the authorities and the text books. A chapter discusses how to teach the unit and how to analyze the difficulties. As an illustration of the method the authors present a detailed study of the unit on positive and negative numbers. The author's unit is rather large since it deals not only with the four fundamental operations on such numbers but includes also division of polynomials by binomials and the solution of quadratic equations. Problems of this kind, however, are not considered as essential parts of the unit but are introduced to test the understanding of the four fundamental operations since the unit can not be considered thoroughly mastered unless the pupil can apply it in all its various surroundings. In the analysis of the pupil's difficulties a thorough study is made of subtraction.

To supervisors and research students the book is a valuable guide on how to study a unit. The classroom teacher will be more interested in the chapters on pupil's difficulties in computation, with vocabulary, and the difficulties due to personal traits. Joseph A. Nyberg.

Manual of the Vertebrate Animals of the Northeastern United States, by David Starr Jordan, Chancellor Emeritus of Leland Stanford Junior University, with an Introduction by Barton Warren Evermann, California Academy of Sciences. Thirteenth Edition, completely revised and enlarged and with illustrations. Cloth. Pages xxxi+445. 1929. World Book Company, Yonkers-on-Hudson, New York. Price $4.00.

The first edition of this well known Manual was published in 1876 and with the editions that have followed it has retained a high rank as a standard reference. The present publishers have accomplished a real service to Zoology by arranging for this last revised edition. A group of notable naturalists, specialists in their fields, have contributed to the value of the Manual by checking the accounts of the species described. In recent years there has been a tendency among teachers of beginning students, in our high schools at least, to get away from the classification of large numbers of specimens. Such a plan may have some value but there are students to day who would both enjoy and profit from an intimate contact with such a book as the Manual of Vertebrates. It should be in the library of every school. J. W. Hadley.

THE TENTH ANNUAL OHIO STATE EDUCATIONAL CONFERENCE.

"Reaching the Individual" will be the keynote of the tenth annual Ohio State Educational Conference to be held in Columbus, Apr. 3, 4, 5, 1930. Mr. Robert M. Hutchins, president of the University of Chicago, will sp ak at the Thursday night general session. Mr. E. H. Southern, well-known actor and dramatic reader, will give a series of readings from Shakespeare Friday night. One additional speaker for the Thursday night general session is yet to be secured.

More than one hundred speakers, including some thirty-five from out of the state, will participate in the tenth annual Ohio State Educational Conference in which a registration of over five thousand is expected. Last year 5,100 were registered.

Visual education will be a new topic for which sectional meetings will be held. This brings the total number of sections to thirty-five. Three sessions of conference (Friday morning and afternoon and Saturday morning) will be given over to these sectional conferences.

One or more meetings will be held by groups interested in each of the following fields of education: adult education, attendance supervisors, school nurses and visiting teachers, biological science, city superintendents, clinical psychology, commercial education, county superintendents, educational and intelligence tests, elementary principals, elementary teachers, English, geography, higher education, high school principals, history, home economics, industrial and vocational education, journalism, junior high school principals, kindergarten and primary teachers, Latin, mathematics, modern language, music, non-biological science, parent-teacher association, physical education, religious education, school business officials, school librarians, special education, teacher training, village and consolidated school superintendents, and visual education.

RESEARCH AIDS RELIGION.

Research has done more to destroy superstition than all other agencies combined. Superstition is the greatest bane of religion. Witchcraft, the evil eye, dragons, fateful conjunctions of stars and planets, baleful influences of comets, and ominous phases of the moon are dead to civilization, killed by the findings of science. Epidemics and plagues are no longer visitations of God but are caused by living enemies of mankind which may be thwarted or destroyed.